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STUDIES ON THE BEHAVIOR OF FUSARIUM CROMYOPHTHORON IN CARBOHYDRATES, GLUCOSIDES, PROTEINS AND VARIOUS DECOCTIONS, WITH A DISCUSSION ON THE "ISOMETABOLIC POINT" OF SUBSTANCES

CHRISTOS P. SIDERIS[1]

INTRODUCTION

There is some confusion among students of microbiological physiology on the nature of the metabolic products released in the solution as a result of the reaction of various fungi and bacteria with different culture media. This confusion appears quite often in the literature in the statements of different investigators on the behavior of the same organism.

The writer, by careful technique, has been able to study the nature of certain of these metabolic products and particularly that concerned with the changes produced in the hydrogen-ion concentration of different culture media during the growth of *Fusarium cromyophthoron* Sid. (16). He found, by frequent determinations of the changes of the hydrogen-ion concentrations, that the behavior of the organism was constant under any set of conditions, and was able also to reconcile the contradicting views of the different investigators. He found, in other words, that Fusaria may change the reaction of their substratum either by increasing or decreasing the hydrogen-ion concentration, the nature of the reaction depending (a) on the initial pH value of the culture solution, (b) on the chemical nature of the nutrient substance employed and (c) on the age of the culture.

This paper is concerned (a) with an analysis of the behavior of *F. cromyophthoron* in different culture media, (b) with a reconciliation of the views of previous investigators on the behavior of a number of organisms in different culture media, and (c) with a discussion on the "isometabolic point" of substances, *e.g.* of the initial pH value of the culture solution which may be changed slightly or not at all by the reaction of the metabolic products of an organism during the assimilation of a certain nutrient substance.

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REVIEW OF LITERATURE

There are a number of excellent publications concerned with the behavior of various fungi and bacteria in different culture media. Those of quite recent origin are particularly concerned with the changes produced by microorganisms in the H-ion concentration of their culture media; it is these which will be considered in this presentation.

In a review on the behavior of different Fusarium species and other organisms in different culture media, we find that organisms in general behave differently at different stages of their development. For instance, Young and Bennett (22), in growing *F. oxysporum* Scht. in culture media at different initial pH values, found that

> . . . the reaction of the culture solution in which *F. oxysporum* was grown continued to become acid until an H-ion concentration of pH 3.6 was reached, then turned toward alkalinity and growth continued until all the organic compounds were broken up and an H-ion concentration of pH 8.4 was reached.

Johnson (7), in studying the resistance of seven molds, including *F. bullatum* and *F. oxysporum*, found that

> . . . the optimum reaction for the molds lies more to the acid side of the neutral point than toward the alkaline, practically all of them show nearly a maximum growth as low as pH 2.0, while they are cut off quite sharply at pH 8.7. The reaction of all the solutions was changed toward a more alkaline value except the neutral solution with *F. bullatum*. In no case did the molds reach the pH values which were found to inhibit their growth in the studies on the effect of hydroxyl ions.

Sideris (18), in his studies on the behavior of *Fusarium cromyophthoron* in onion decoctions at different initial H-ion concentrations, found that the organism changed the reaction of all the cultures except that at pH 5.5; those between pH 3.0 and 5.5 were changed toward the latter value by a decrease of their H-ion concentration, and those between pH 7.5 and 5.5 were also changed toward the latter value by an increase of their H-ion concentration. Weimer and Harter (10) report that the following organisms changed the H-ion concentration of a 10 per cent glucose solution as follows: *Fusarium acuminatum*, pH 3.97 to 3.89; *Diplodia tubericola*, pH 3.97 to 3.66; *Rhizopus tritici*, pH 4.94 to 2.11; *Mucor racemosus*, pH 5.44 to 3.09; *Sclerotium bataticola*, pH 4.54 to 4.21; *Penicillium sp.*, pH 5.70 to 4.37; *Botrytis cinerea*, pH 4.99 to 3.24; and *Sphaeronema fimbriatum*, pH 5.19 to 5.50. Harter and Weimer (4) report that *Rhizopus tritici* Saito changed the initial pH value of culture solutions of different nutrient substances as follows: string bean decoction, pH 4.80 to 7.99; prune decoction, pH 3.91 to 3.53; Irish potato decoction, pH 5.60 to 7.80; carrot decoction, pH 4.98 to 4.47; turnip decoction, pH 4.83 to 4.26; sweet potato decoction, pH 5.05 to 3.31; Czapek's solution, pH 4.14 to 2.47; Pfeffer's solution, pH

3.48 to 2.61; Richard's solution, pH 3.36 to 2.46, and beef bouillon pH 8.04 to 8.52. MacInnes (9), in a study on the behavior of *Fusarium sp.*, found that

> . . . as growth proceeds the H-ion concentration of the solution is changed by the organism, those on the acid side tending to become more alkaline and those on the alkaline side more acid.

Paine and Chaudhuri (12) report that *Bacillus solanisaprus* Harr. changed the initial pH of an Irish potato decoction from pH 6.4 to 4.8, and *Bacillus atrosepticus* v. Hall, the same decoction from pH 6.4 to 7.2. Rosen (15) reports that his organism, *Bacillus alboprecipitans* Rosen, changed the pH value of beef broth from 7.2 to 8.0. Wolf (21) states that some pathogenic bacteria grown in media containing pectin changed the pH of the solution as follows: *Bacillus carotovorus* Jones, pH 7.4 to 5.2; *Bacterium tabacum*, pH 7.4 to 6.4; *Bacterium angulatum*, pH 7.4 to 6.4; *Bacterium sojae*, pH 7.4 to 6.8, and *Bacterium campestre*, pH 7.4 to 6.0. Dernby (3), in studying the behavior of a number of bacteria at different hydrogen-ion concentrations, expresses the opinion that bacteria may be classified into distinct groups according to the changes they produce in the H-ion concentration of their substrata.

The above citations on the behavior of a number of organisms, and particularly of Fusaria, lead to the conclusions (a) that different organisms may or may not behave alike in the same or different nutrient substances, (b) that the tendency in the majority of the organisms is to increase the H-ion concentration of the solution in cultures containing available carbohydrates and decrease it in those containing available proteins, and (c) that the reactions produced in certain vegetable and meat decoctions depend to a considerable extent on the initial hydrogen-ion concentration and the ratio of available carbohydrates to proteins contained in the particular decoction.

METHODS OF EXPERIMENTATION

The methods employed in these studies aimed to yield a certain understanding of the operation of the various factors which initiate the changes in the H-ion concentration of certain culture media during the growth of some microorganisms. For the purpose, substances of a chemically different constitution were used for the growth of the organism with the expectation that the resulting metabolic products would react differently on the hydrogen-ion concentration of the culture solution. The different nutrient substances employed belong chemically to the following classes of substances: carbohydrates, glucosides, proteins, and animal and vegetable decoctions. They were used in different amounts for the preparation of the

different culture media For instance, for the preparation of dextrose solutions, 2 per cent dextrose was used; for starch solution, 1 per cent potato starch; for pectin solution, 0.6 per cent pectin; for amygdalin solutions, 1 per cent amygdalin; for peptone solutions, 1 per cent peptone; for beef extract solutions, 1 per cent beef extract; and for onion decoctions, 20 per cent onions (18). The different nutrient substances were prepared into culture media by placing the amount designated in a solution of inorganic salts of the following proportion: distilled water 1000 cc., $MgSO_4$ 2.12 grams, $Ca(NO_3)_2$ 0.71 grams, KH_2PO_4 1.36 grams, and $Fe(NO_3)_3$ 1 cc. of a 5 per cent solution. The different cultures were adjusted to definite H-ion concentrations with additions of 0.2 normal HCl and KOH.

The apparatus devised by the writer (17) and used in other studies was employed, also, for the growth of *F. cromyophthoron*. The determinations of the changes in the H-ion concentration were made by the colorimetric method of Clark and Lub (2). The volume of culture solution removed from the flask for the determination of the H-ion concentration was in every case between five and ten cubic centimeters. With heavily colored solutions, the H-ion concentration was estimated by an Hildebrand hydrogen electrode (5).

BEHAVIOR IN CARBOHYDRATES

The carbohydrate substances, used for the growth of *F. cromyophthoron* and the study of the resulting changes in the hydrogen-ion concentration of the culture solution, were dextrose, potato starch and pectin.

Dextrose, a hexose sugar, is well known to all students of microbiology for its availability to a greater number of fungi and bacteria than any other known sugar. Certain of the metabolic products released in the culture solution by different micro-organisms during the assimilation of dextrose are alcohols and various organic acids. Certain organisms are quite specific in the production of these substances.

The assimilation of dextrose by micro-organisms is not thoroughly understood, due possibly to insufficient experimentation. It is not known whether the entire dextrose molecule penetrates the cell membrane and enters the cell as it is, or is broken into simpler substances and taken as such before penetration. With animal cells, we have the information that both dextrose and levulose molecules diffuse through the cell membrane without undergoing, previously, any changes (10). The procedure which micro-organisms employ for the assimilation of dextrose constitutes quite an important question, because it is related with the resistance of the protoplasm in high concentrations of various organic acids and alcohols. Although experimenters have been able to produce, by means of enzymes, organic acids and alcohols similar to those obtained by the reactions of the

living organism, nevertheless they have not been able to settle satisfactorily the question on the assimilation of the dextrose molecule.

The assimilation of potato starch or pectin by micro-organisms is more difficult to understand than that of dextrose. Either potato starch or pectin, before they become assimilable, must be broken into simpler compounds, *e.g.*, hydrolyzed to dextrose in the case of the potato starch, or to some pentose sugar in the case of pectin.

The reactions produced in the various carbohydrates by the organism are recorded in tables 1, 2, and 3.

TABLE 1.—*Changes produced in the initial pH of a 2 per cent dextrose solution by F. cromyophthoron, from October 15 to November 15, 1923*

Date 1923	Culture solutions of different initial pH					
	pH 3.0	pH 4.0	pH 5.0	pH 6.0	pH 7.0	pH 8.0
10/15	3.0	4.0	5.0	6.0	7.0	8.0
10/25	3.6	3.8	4.4	4.8	6.0	6.3
10/28	3.8	3.8	4.0	4.0	5.3	5.8
10/30	3.8	3.8	3.8	4.0	5.0	5.5
11/5	3.8	4.5	3.8	4.8	4.8	5.4
11/9	4.2	4.8	4.0	5.6	4.6	5.4
11/15	5.0	5.4	4.8	6.0	4.8	5.6

TABLE 2.—*Changes produced in the initial pH of a 1 per cent potato starch solution by F. cromyophthoron, from October 15 to November 15, 1923*

Date 1923	Culture solutions of different initial pH					
	pH 3.5	pH 4.5	pH 5.0	pH 6.0	pH 7.0	pH 8.0
10/15	3.5	4.5	5.0	5.6	6.8	7.8
10/20	3.9	4.2	5.0	5.5	6.4	7.5
10/25	4.2	4.4	5.0	5.3	5.8	6.8
10/30	4.4	4.6	5.3	5.5	5.8	6.4
11/5	4.6	4.9	5.6	6.0	6.4	6.6
11/10	4.9	5.2	6.0	6.3	6.6	7.0
11/15	5.2	5.6	6.2	6.5	7.0	7.2

TABLE 3.—*Changes produced in the initial pH of a 0.6 per cent pectin solution by F. cromyophthoron, from October 15 to November 15, 1923*

Date 1923	Culture solutions of a different initial pH					
	pH 3.0	pH 4.0	pH 5.0	pH 6.0	pH 7.0	pH 8.0
10/15	3.0	4.0	5.0	6.0	7.0	8.0
10/20	3.2	4.4	5.2	6.4	7.0	7.6
10/25	3.8	5.0	5.8	6.6	6.8	7.2
10/30	5.0	5.6	6.2	6.6	6.6	7.0
11/5	5.8	6.2	6.4	6.4	6.5	6.8
11/10	6.2	6.4	6.5	6.5	6.6	6.8
11/15	6.2	6.8	7.0	7.2	7.4	7.0

Explanations on the Behavior in Carbohydrates

The results in tables 1, 2, and 3 indicate that the products released during the assimilation of dextrose, potato starch, and pectin by *F. cromyophthoron* may increase or decrease the acidity of the culture solution, the reaction depending on the initial pH of the culture and the chemical nature of the nutrient substances employed.

The behavior of *F. cromyophthoron* in dextrose solutions at different initial pH, in table 1, is manifested by an increase of the hydrogen-ion concentration in the cultures between pH 8.0 and 4.0, and by a decrease in those between pH 3.0 and 4.0. It becomes obvious from the behavior of this organism that the "isometabolic point" of dextrose lies at or near pH 3.8. This pH value suffered only slight changes by the reaction of the metabolic products during the assimilation of dextrose by *F. cromyophthoron*, while other initial pH values, either above or below this point, were changed to a degree almost proportional to their distance from the "isometabolic point."

The sudden changes in the hydrogen ion concentration of the cultures, manifested by an increase of the pH value at the later part of the growth of the organism, were due to the autolysis of the mycelium, the products of autolysis being ammonia or other alkaline reacting substances—not different from those obtained generally from protein hydrolysis.

The nature of the reactions produced by the organism in potato starch and pectin followed the same order of behavior observed in dextrose solutions, *e.g.*, the initial pH value of certain cultures was either increased or decreased or remained constant. There is, however, a difference in the position occupied by the "isometabolic point" of the two different substances. The position occupied by the "isometabolic point" of potato starch lies near or at pH 5.2 and that of pectin near or at pH 6.5. The differ-

ence in the position of this point is possibly due either to a certain difference in the reaction of the metabolic products of the different sugars, or to a difference in the amount of sugars and other substances released during the hydrolysis of potato starch and pectin. Morever, the enzymes released by the organism for the hydrolysis of pectin and potato starch may interfere and even modify the extent of the changes in the initial hydrogen ion concentration of the culture solution and the position of the "isometabolic point."

BEHAVIOR IN GLUCOSIDES

For the study of the behavior of *F. cromyophthoron* in glucosides amygdalin was used. The molecular constitution of this substance is known as well as the products of its hydrolysis. The substances obtained when amygdalin is acted upon by emulsion are glucose, benzaldehyde, and hydrocyanic acid. In spite of the poisonous properties of hydrocyanic acid, the fungus could thrive and reproduce normally. Qualitative tests proved that the organism utilizes amygdalin in the hydrolysed form; all of the three products of hydrolysis by emulsin were found to exist in cultures in which the organism was left in contact with amygdalin for a certain length of time.

The changes produced in the initial H-ion concentration of various cultures by the action of *F. cromyophthoron* on amygdalin are recorded in table 4.

TABLE 4.—*Changes produced in the initial pH of a 1 per cent solution of amygdalin by F. cromyophthoron, from October 15 to November 15, 1923*

Date 1923	Culture solutions of a different initial pH					
	pH 3.0	pH 4.0	pH 5.0	pH 6.0	pH 7.0	pH 8.0
10/15	3.0	4.0	5.0	6.0	7.0	8.0
10/20	3.5	4.5	5.0	5.8	6.5	7.4
10/25	4.5	5.0	5.0	5.2	6.0	6.6
10/30	5.0	5.0	5.2	5.0	5.2	5.5
11/5	5.0	5.2	5.2	5.0	5.0	5.2
11/10	5.2	5.4	5.4	5.2	5.2	5.4
11/15	5.4	5.6	5.8	5.4	5.6	5.8

Explanation on the Behavior in Glucosides

F. cromyophthoron is capable of changing the reaction of amygdalin solutions of different initial pH by either increasing or decreasing the H-ion concentration, the nature of the reaction and the extent of the changes depending on the initial pH of the particular culture. In cultures

between pH 3.0 and 5.0, the reaction was changed by the organism by decreasing the H-ion concentration, in those between pH 5.0 and 8.0, by increasing it. The changes produced by the organism in the culture with initial pH 5.0 were practically nil. The behavior of the organism toward this pH value, *e.g.*, pH 5.0, in amygdalin solutions is comparable to that already observed in dextrose solutions at pH 3.8. Therefore, the "isometabolic point" of amygdalin is at or near pH 5.0.

It has been ascertained by chemical tests that the organism utilizes amygdalin in the hydrolysed form. It is not known, however, whether, besides glucose, hydrocyanic acid and benzaldehyde are utilized as they are produced or changed into some other form. If we assume, for the sake of argument, that benzaldehyde and hydrocyanic acid are not utilized, then two things ought to result: first, an accumulation of hydrocyanic acid and benzaldehyde in great quantities, and second, a reaction in the solution not differing from that of dextrose solutions in table 1, *e.g.* the isometabolic point of amygdalin ought to be near pH 3.8 and not at pH 5.0, if dextrose *alone* was assimilated. With an accumulation of great quantities of hydrocyanic acid, it is possible that the life of the organism may be endangered. As none of these reactions have been observed to take place, it is possible that both hydrocyanic acid and benzaldehyde are utilized to a certain extent in some form, and influence in this way the reaction of the solution. There are a number of changes which benzaldehyde may suffer, as well as hydrocyanic acid, which may render them available to the organism. Benzaldehyde, for example, may undergo auto-oxidation, add on hydrocyanic acid and hydrogen, or be changed to *hydrobenzamide* ($(C_6H_5CH)3N_2$) by the union of three molecules of benzaldehyde and two molecules of ammonia (6).

BEHAVIOR IN PROTEINS

Peptone, a protein derivative, was employed for the study of the behavior of *F. cromyophthoron* in protein solutions. The molecular constitution of peptone is not known. The resulting products of peptone hydrolysis are amino acids. The amino acids are substances containing one or more amino-groups in direct union with carbon and are both basic and acidic simultaneously, because of the reactivity of the amino and carboxyl radicals.

The manner in which proteins are assimilated by fungi is not well understood. Proteins, before they become assimilable, are hydrolysed into amino acids and may be utilized as such in certain cases, or broken into simpler compounds. It is known that certain bacteria under anaerobic conditions have the power of splitting off the amino group whereas under aerobic con-

ditions they split off the carboxyl group. In higher animals, proteins are hydrolysed into amino-acids and used as such. The question therefore arises: is the amino-acid molecule taken into the fungal cell as it is, or is it broken into its simpler compounds, fatty acids, ammonia, or other different substances before it is assimilated? As the reactions of the organism show, in table 5, this constitutes a very important question, because it is related with the resistance of the protoplasm in high concentrations of hydroxyl ions.

The reactions produced by *F. cromyophthoron* in peptone solutions are recorded in table 5.

TABLE 5.—*Changes produced in the initial pH of 1 per cent peptone solution by F. cromyophthoron, from October 15 to November 15, 1923*

Date 1923	Behavior in culture solutions of different initial pH					
	pH 3.0	pH 4.0	pH 5.0	pH 6.0	pH 7.0	pH 8.0
10/15	3.0	4.0	5.0	6.0	7.0	8.0
10/20	4.5	4.8	6.0	7.0	7.4	7.8
10/25	6.0	6.4	7.0	7.4	7.6	8.0
10/30	6.6	7.2	7.4	7.6	8.0	8.2
11/5	7.2	7.6	7.8	8.0	8.2	—
11/10	7.4	7.8	8.0	8.2	8.4	—
11/15	7.6	7.8	8.2	8.4	8.6	—

Explanations on the Behavior in Proteins

The behavior of *F. cromyophthoron* in peptone solutions at different initial pH, as it appears in table 5, indicates that the metabolic products decreased the hydrogen-ion concentration practically of every culture, regardless of its initial pH value. Chemical tests proved that the organism liberated ammonia in the solution during the assimilation of peptone. It is evident, therefore, that the decrease observed in the hydrogen-ion concentration of the different cultures was produced by the hydroxyl ions, resulting from the reaction of ammonia with water. The liberated ammonia was undoubtedly derived from the various amino-acids obtained from peptone by hydrolysis.

The nature of the reactions produced in peptone solutions by the above organism differs essentially in principle from that already observed in both dextrose and amygdalin solutions. No peptone solution ever showed properties such as have been observed in dextrose solutions at pH 3.8 and amygdalin solutions at pH 5.0. In other words, peptone solutions were one-direction reactions, *viz.*, toward increased alkalinity, and not ampho-

teric, as was the case with dextrose and amygdalin. The slight increase in the hydrogen-ion concentration, appearing at pH 8.0, was possibly due to the influence of the HCO_3 ions, resulting from the reaction of CO_2 with water.

The growth in mycelium development attained by the organism in peptone solutions at pH 6.0 and 7.0 was meager, and almost insignificant at pH 8.0, compared to that at pH 3.0, 4.0, and 5.0. The difference in the growth of the organism is undoubtedly due to the toxicity exerted by higher concentrations of hydroxyl ions in the cultures at initial pH 6.0, 7.0 and 8.0. High concentrations of hydroxyl ions may either flocculate the protoplasm of the organism or increase the permeability of the cell membrane (11). The inability of the organism to establish an "isometabolic point," it may not be strange to suppose, was due to the toxicity of high concentrations of hydroxyl ions, increasing in proportion with the decomposition of amino acids.

BEHAVIOR IN VEGETABLE AND ANIMAL DECOCTIONS

The studies on the changes produced in the initial pH of animal and vegetable decoctions by *F. cromyophthoron* were made by using beef extract and onion decoction. Both these substances are composed of mixtures of various properties of carbohydrates, glucosides, and proteins. The reactions produced in the medium as a result of the hydrolysis of these substances may influence the nature of the changes in the initial pH of the culture solution to an extent depending on the ratio of carbohydrates to proteins available in the media.

The changes produced by *F. cromyophthoron* in the initial pH of culture solutions of beef extract and onion decoction are recorded in tables 6 and 7.

TABLE 6.—*Changes produced in the initial pH of a 1 per cent beef extract solution by F. cromyophthoron, from October 15 to November 15, 1923*

Date 1923	Culture solutions of different initial pH					
	pH 3.0	pH 4.0	pH 5.0	pH 6.0	pH 7.0	pH 8.0
10/15	3.0	4.0	5.0	6.0	7.0	8.0
10/20	4.0	5.0	5.5	6.5	7.0	7.8
10/25	6.0	6.8	7.0	7.2	7.2	7.4
10/30	7.0	7.2	7.2	7.2	7.3	7.5
11/5	7.2	7.2	7.2	7.4	7.4	7.7
11/10	7.2	7.4	7.4	7.6	7.6	8.0
11/15	7.4	7.5	7.6	7.8	8.0	8.2

TABLE 7.—*Changes produced in the initial pH of a 20 per cent onion decoction by F. cromyophthoron, from October 15 to November 15, 1923*

Date 1923	Culture solutions of different initial pH					
	pH 3.0	pH 4.0	pH 5.0	pH 6.0	pH 7.0	pH 8.0
10/15	3.0	4.0	5.0	6.0	7.0	8.0
10/20	3.5	4.2	4.8	5.5	6.5	7.5
10/25	4.0	4.4	5.0	5.5	6.0	7.2
10/30	4.2	4.5	5.0	5.2	5.8	6.0
11/5	4.4	4.7	5.1	5.1	5.5	5.8
11/10	4.6	5.0	5.3	5.7	6.2	6.4
11/15	4.8	5.0	5.8	6.0	6.4	6.8

Explanation on the Behavior in Decoctions

The behavior of *F. cromyophthoron* in relation to the development of changes in the initial pH value of beef extract solutions and onion decoctions differed in the two cases. The organism changed but slightly the initial reaction of beef extract solutions at pH 7.2 and onion decoctions at pH 5.0; it produced, however, considerable changes in the remainder of the cultures of both media whose position on the pH scale was above or below the values mentioned. It follows, therefore, that the values pH 7.2 and 5.0 represent the "isometabolic point" of the two respective nutrient substances. The difference in the position of the "isometabolic point" on the scale of the pH values is possibly due to a corresponding difference in proportion of available carbohydrates, glucosides and proteins contained in the two different substances. The proportion of available carbohydrates to proteins is greater in the onion decoctions and smaller in the beef extract solutions. The ratio, therefore, of carbohydrates to proteins is the determining factor for the quantities of organic acids and alkaline reacting substances formed in the culture solution which correspondingly influence the position of the isometabolic point.

The slight acidity produced in the culture solution at pH 5.0, in table 7, at the early part of the growth of the organism was possibly due to the bicarbonate ions resulting from the reaction of CO_2 with water. The reactions produced in the remaining cultures, in tables 6 and 7, during the later growth of the organism, show a gradual decrease in the hydrogen-ion concentration. The nature of the reactions formed in the culture media during this period is due to the autolysis of the mycelium of the fungus and not to the reaction of the (proper) metabolic products.

The nature and extent of the reactions produced by organisms in culture media depend (a) on the chemical composition of the nutrient substance, and (b) on the initial reaction (pH value) of the particular culture.

DISCUSSION ON THE "ISOMETABOLIC POINT" OF NUTRIENT SUBSTANCES

The term "isometabolic point" is introduced in this presentation for the purpose of naming that initial reaction of culture solutions of any nutrient substance which, during the metabolic activities of an organism, is not altered in the concentration of the hydrogen or hydroxyl ions to any great extent by the reaction of the released metabolic products. It designates, in other words, that initial hydrogen-ion concentration of the culture solution of a nutrient substance which may or may not be changed slightly during the growth of an organism by the reaction of its metabolic products. The initial pH value of the cultures (of the same nutrient substance) whose position on the scale of pH values lies on either side of the "isometabolic point" is changed by the reaction of the metabolic products toward that of the "isometabolic point." This is accomplished by the reactions of the organism with the culture media which, in those cultures on the alkaline side of the "isometabolic point," tend to increase the hydrogen-ion concentration and decrease it in those on the acid side. The reactions, in this respect, however, are not controlled by the wilful operations of the organism, but by the chemical nature of the released metabolic products and possibly by other unknown biochemical factors. It must be kept in mind that the reaction at the "isometabolic point" is only maintained constant so long as some of the nutrient substance lasts in the culture medium. With the removal of the very last portion of this substance from the culture solution by the organism, the reaction changes suddenly toward alkalinity, due either to the development of reverse reactions in the metabolic products, or to the setting in of autolysis in the mycelium of the fungus.

The reactions produced in the culture solutions of the different nutrient substances, in tables 1 to 7, as a result of the growth of *F. cromyophthoron*, indicate that at certain initial pH values the organism can utilize many of these substances without disturbing the initial reaction either by an increase or decrease of the hydrogen ion concentration. The behavior of the organism, in this respect, tends to prove that there is some connection between certain hydrogen ion concentrations and the utilization of certain nutrient substances, the exact nature of which is baffling. It may be that at the "isometabolic point" the reaction is at equilibrium, *e.g.*, the organic acids and organic bases are formed in equivalent quantities in the culture solution and neutralized just as fast as they are liberated. Or it may be due to the buffer reaction of the culture solution in each particular case. The

ions mainly responsible for the development of the reactions, which increased or decreased the hydrogen-ion concentration of the different culture solutions or maintained it constant, were those of the organic and, to a certain extent, inorganic acids, on the one hand, and the CO_3 and NH_4 ions, on the other hand. The acids, for instance, increased the hydrogen-ion concentration of the dextrose solution of the cultures at pH 8.0, 7.0, 6.0 and 5.0 toward pH 3.8, in table 1, and the CO_3 and NH_4 ions decreased the same in the cultures at pH 3.0 toward pH 3.8. The extent of the acids and alkalies formed in the culture media is controlled by the organism. The organism can grow in culture media at hydrogen-ion concentrations as high as pH 2.0 and as low as pH 10.0. Neither acids nor alkalies, formed in the culture media by the reactions of the organism, ever reached the above two extreme hydrogen-ion concentrations. The point, therefore, which is indicated as "isometabolic point" represents a hydrogen-ion concentration connected with certain nutritional or metabolic phases and not with the critical or death point of the organism.

The amphoteric nature of the reaction produced during the utilization of different nutrient substances by *F. cromyophthoron* suggests, to an analogous degree, the amphoteric nature of proteins (8). It is possible to make comparisons of the reactions of the isoelectric point of proteins and of the isometabolic point of substances, in certain phases. The studies of Robbins (13, 14) on the behavior of vegetable tissues at different hydrogen-ion concentrations indicate that the reaction of these tissues was amphoteric and isoelectric at certain pH values. Robbins's observations are very interesting and deserve a more extensive study.

The factors which, in general, seem to be responsible for the position which the "isometabolic point" occupies in the scale of pH values, during the utilization of a nutrient substance by an organism, are the following: (1) the ratio of available carbohydrates to proteins contained in a nutrient substance, (2) the resistance of the organism to the initial hydrogen or hydroxyl ion concentrations of the culture media, and (3) the resistance of the organism to the various products of hydrolysis or of metabolism which might be high concentrations of either hydrogen or hydroxyl ions, or other deleterious substances such as hydrocyanic acid, certain aldehydes and alcohols. The following citations explain the operation of the above factors in a number of cases. Harter and Weimer (4) report, in their studies on the behavior of *Rhizopus tritici* in various vegetable decoctions, that the initial reaction of prune, carrot, turnip and sweet potato decoctions was changed from less acid to more acid; and in Irish potato and string bean decoction, from acid to alkali. If we take for criterion the chemical composition of the tissues which were employed for the prepara-

tion of the different decoctions in order to explain the nature of certain of the reactions formed, we find that the prune, carrot, turnip and sweet potato decoctions contain more available carbohydrates, according to Wehmer (19), than the Irish potato and string bean decoctions. It is clearly seen that the increase which resulted in the initial hydrogen-ion concentration of the cultures of the former decoctions, and the decrease in the same of the latter were due to the difference in the chemical composition of the tissues. Paine and Chaudhuri (12) report, in their studies on the behavior of *B. solanisaprus* and *B. atrosepticus* in potato decoction, that the former organism changed the reaction of the decoction from pH 6.4 to 4.8 and of the latter from 6.4 to 7.2. It is interesting to consider, in this connection, also certain other reactions produced by both organisms on potato. From these it becomes evident that *B. atrosepticus* utilized the proteins of the potato for nutritional purposes and *B. solanisaprus* the carbohydrates. The difference in the behavior of the two organisms in the same nutrient substance was due to the reaction of the metabolic products resulting from the differential nutritional requirements of the organisms. The utilization of the carbohydrates of the potato by one of the organisms and of the proteins by the other constitutes a question not depending on the wilful preference of the organism for either of the substances, but on other physiological causes. It might be a question of susceptibility to certain hydrogen-ion concentrations resulting from either of the substances mentioned during the metabolic activities of the organism, or of inability to release the proper enzyme for the hydrolysis of the nutrient substance. Rosen (15) reports as follows on the behavior of *B. alboprecipitans* in culture media at different hydrogen-ion concentrations: (a) that his organism grew well in culture media at pH 6.6, 7.2, 7.4, and 7.6, but not at pH 4.8, 5.0, 8.5, 8.6, and 9.8, (b) that in carbohydrates the growth was meager in comparison to that obtained in beef broth, and (c) that the organism was unable to utilize carbohydrates, viz., various simple sugars, when furnished alone, but was able to do so when the sugars were mixed with beef broth. The behavior of *B. alboprecipitans*, in the first case, was due to the susceptibility to hydrogen ion concentrations higher than pH 5.0 and lower than pH 8.5. In the second case, the organism was unable to utilize the different simple sugars and produce an appreciable growth, because the resulting concentrations of hydrogen ions were sufficiently high to inhibit the growth of the organism. The profuse mycelial growth attained by the organism in beef broth was due to the chemical composition of this substance, the quantity of available carbohydrates to proteins being of such a proportion as to permit the organism to utilize the substance completely without producing changes in the initial reaction toxic to the welfare of the organism. In

the third case, the ability of the organism to utilize sugars when mixed with beef broth was due to the favorable hydrogen-ion concentrations resulting from the reaction (probably neutralization) of oppositely charged metabolic products released from the two different nutrient substances.

The reactions produced in the surrounding solution by the metabolic products of micro-organisms from different nutrient substances, considered together with the susceptibility of various microorganisms to certain hydrogen-ion concentrations, may constitute a factor of considerable importance for the initiation or inhibition of many diseases. The behavior of *F. cromyophthoron* and of the organisms mentioned in the preceding paragraph is of interest not alone to the plant physiologist but to the plant pathologist as well. The different reactions produced by parasites during the utilization of host tissues may be employed by plant pathologists to obtain some information on the methods of the parasite and to understand, to a certain extent, the nature of the disease. With organisms very sensitive to the slight changes of hydrogen-ion concentrations, it is easy to see how the resulting reactions in the surrounding solution may influence the initiation or inhibition of a disease. The sources from which appropriate hydrogen-ion concentrations may be released, for the initiation or inhibition of various fungal and bacterial diseases, are: (a) the tissues of the host, and (b) the soil solution. The former may furnish a number of hydrogen-ion concentrations due to fluctuations in the sap acidity and in the composition of the tissues, as far as the ratio of carbohydrates to proteins is concerned, at different seasons of the year and different stages of growth. The latter, in an analogous manner, may furnish a number of hydrogen-ion concentrations, due either to reactions in the mineral constituents of the soil solution or to biological reactions.

SUMMARY

Fusarium cromyophthoron, grown in culture media of different nutrient substances at different initial hydrogen-ion concentrations, formed substances (metabolic products) which, in certain cases, maintained constant the initial reaction of the culture solution and, in others, either increased or decreased the hydrogen-ion concentration. In dextrose solutions, the hydrogen-ion concentration was increased in the cultures at initial pH 4.0, 5.0, 6.0, 7.0, and 8.0, and decreased at pH 3.0; the final reaction in the majority of the cultures pointing toward pH 3.8. In amygdalin solutions, the hydrogen-ion concentration was increased in the cultures at pH 6.0, 7.0, and 8.0, and decreased at pH 3.0 and 4.0; the final reaction in this substance pointing toward pH 5.0. In peptone solutions, the hydrogen-ion concentration was decreased practically in every culture, viz., at

pH 3.0, 4.0, 5.0, 6.0, 7.0, and 8.0. In potato starch solutions, the hydrogen-ion concentration was increased in the cultures at pH 6.0, 7.0, and 8.0, and decreased at pH 3.0, 4.0, and 5.0; the final reaction pointing toward pH 5.2. In pectin solutions, the hydrogen-ion concentration was increased in the cultures at pH 7.0 and 8.0, and decreased at pH 3.0, 4.0, 5.0, and 6.0; the final reaction pointing toward pH 6.4. In beef broth, the hydrogen-ion concentration was increased in the cultures at pH 8.0, and decreased at pH 3.0, 4.0, 5.0, 6.0, and 7.0; the final reaction pointing toward pH 7.4.

To the particular hydrogen-ion concentration toward which the final reaction was pointing, in the cultures of the different nutrient substances, the term "isometabolic point" has been assigned. Therefore, the "isometabolic point" of dextrose solutions lies near or at pH 3.8, that of amygdaline at pH 5.0, of potato starch at pH 5.2, of pectin at pH 6.4, and of beef broth at pH 7.4. The initial reaction of the cultures at the pH value of the "isometabolic point" was maintained more or less constant during the growth of the organism.

The reactions of the metabolic products, formed during the growth of microorganisms on different vegetable tissues and particularly host tissues, may be profitably employed by the plant pathologists to obtain some information on the methods of parasites in the development of diseases.

UNIVERSITY OF CALIFORNIA,
BERKELEY, CALIF.

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A PRELIMINARY STUDY OF FUNGOUS ACTION AS THE CAUSE OF DOWN CORN

L. W. Durrell[1]

With Four Figures in the Text

The breaking of corn stalks in the fall before the crop is harvested, as shown in figure 1, not only results in considerable financial loss due to rot-

Fig. 1. Broken plants in this field resulted from the fungous invasion of the nodes, coupled with a high wind.

[1] The writer wishes to acknowledge the assistance of Dr. I. E. Melhus, Pathologist, Iowa State Agricultural College, for helpful suggestions in the work and in preparation of the manuscript; and also valuable suggestions offered by J. Pinsky, Colorado Agricultural College.

ting of the down ears, but also increases the cost and inconvenience of harvesting. The cause of this breaking has been attributed to a wide range of agencies by the corn growers, such as high wind, so-called "running out" of varieties, soil depletion, micro-organisms, etc. The lack of proof as to the exact cause of the breaking, coupled with observations extending over a period of seven years, wherein many of the broken stalks were found badly disorganized and frequently infected with micro-organisms, suggested the possibility that the rigidity or stiffness of the stalks had been partially destroyed by certain fungi that were prevalent on the nodes, *i.e.*, *Diplodia zeae*, *Gibberella saubinetti*, *Basisporium gallarum*, and *Fusarium* sp. In order to determine if the invasion by these fungi results in a weakening of the nodes, and why the breaking occurs four or five nodes above the ground, the following experiments were planned and carried out during 1922 and 1923.

METHOD OF TESTING BREAKING STRENGTH OF STALKS

The tests of the strength of healthy and infected nodes of cornstalks were made by using a lever as shown in fig. 2. The cornstalks to be broken were placed on two blocks six inches apart with the node in the center. The distance of six inches was arbitrarily chosen as it was a convenient length and fitted the distance between the centers of most internodes. The lever

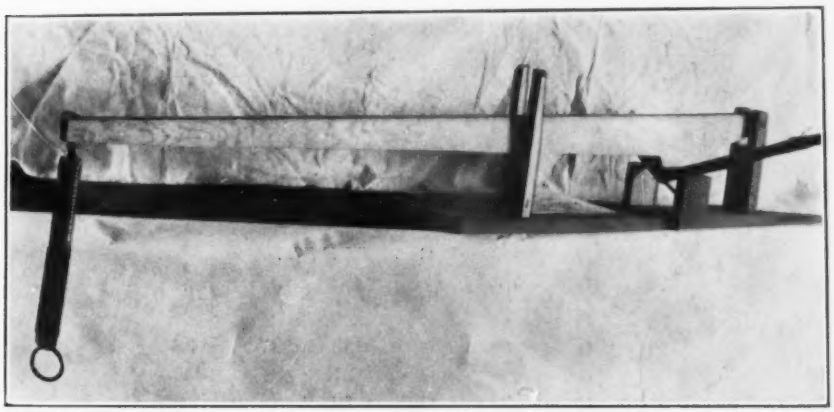

FIG. 2. Lever used in testing breaking strength of stalks.

was forced down upon the node until the stalk broke, a record being made of the pressure exerted on a spring balance. As the lever had a six to one ratio, this pressure was multiplied by six to get the weight necessary to break the stalk. The stalks used were mostly of the variety Iodent grown on the Iowa Experiment Station Farm in 1923. The stalks were taken

directly from this field to the laboratory and broken. The fungus flora was determined by microscopic examination and pure cultural methods after the breaking strength had been determined.

THE BREAKING STRENGTH AND FUNGOUS FLORA OF STALKS IN 1923

Using the above described apparatus, 61 stalks of corn were broken. The stalks were gathered during the season 1923, beginning just before flowering. Uninfected material was obtained at this time. Later in the season infected material was tested. In the following table are given the results of these breaking tests together with the fungous flora of the different infected nodes:

TABLE 1.—*Strength of corn nodes and fungi found in them*

No. of stalk	Node 1		Node 2		Node 3		Node 4		Node 5	
	Fungus flora	Breaking strength pounds	Fungus flora	Breaking strength pounds	Fungus flora	Breaking strength pounds	Fungus flora	Breaking strength pounds	Fungus flora	Breaking strength pounds
1	B	30	D	48	F	18	F	18	F	42
2		150				180		150		
3		198		180		90				
4		180	F	137	D	90	D	60		
										30
6	G	48	G	48	G	36				
										6
8	G	18	G	30	D	30		18		
9	G	54	G	36	D	30	D	24		12
10				126				78		
11	F	60	D	30	F	42				
12	D	30	D	60	G	54	D	36		
13	G	72	G	54	G	48	G	30		
14	G	66	D	84	G	78				
15	H	78	G	150		90	G	84		
16	G	78	G	66	G	90	G	60	G	54
17	G	30	G	36	G	30	G	36	D	18
18			G	6	G	24	G	30		30
19			G	30	G	30	G	30		
20	F	84	D	48	G	36	D	42		
21			G	6	G	18	G	12		
										24
23			G	132	B	114	D	120		120
24			D	54	D	54	D	36	D	18
25				60		54		49		30
26			D	276	D	210	D	156		156
27		156		192		162		120		72

TABLE 1 (*Continued*).—*Strength of corn nodes and fungi found in them*

No. of stalk	Node 1		Node 2		Node 3		Node 4		Node 5	
	Fungus flora	Breaking strength pounds	Fungus flora	Breaking strength pounds	Fungus flora	Breaking strength pounds	Fungus flora	Breaking strength pounds	Fungus flora	Breaking strength pounds
28				276		216		168		144
29				132		90				66
30				306				204		108
31				60		36		24		42
32						120		96		60
33		90	F	144				96		72
34		90	F	126				96		
35	F	90		66		84		36		
36				120		84		48		48
37				144				90		
38	G	126			G	72		60		
39	F	30				36		36		
40		84		72						
41		330		216				56		
42		306		138						108
43		186		150		90				
44				132		96		84		
45		162				132		102		
46		252				132				
47		132		102				66		
48		234				138		126		102
49		168				102				
50		120		90		66				42
51		144				96				
52		174				144		90		
53		114				84				53
54		126				84		54		
55		102		84		60		48		
56				174		174		150		108
57		150		120		72				18
58				66		54		36		12
59		162				132				96
60		120				90		84		48
61		150				132		84		78

D—*Diplodia zeae*
G—*Gibberella saubinettii*
B—*Basisporium gallarum*
F—*Fusarium* sp.

Of the 213 nodes broken, 82 were infected with one of the following fungi: *Diplodia zeae*, *Gibberella saubinetti*, *Basisporium gallarum*, or *Fusarium* sp. It is important to note that in the case of infected stalks infection most frequently occurs at the second, third and fourth nodes. The cause of the frequent infection of these nodes has been described and explained by the author (1, 2)as due to the earlier loosening of the leaf sheath of the lower leaves from the stalk, permitting the inoculum to gain entrance, and to the greater moisture near the ground favoring infection. The general effect of these organisms on the tissues at the nodes is shown in figure 3.

FIG. 3. Corn node split to show disintegration caused by fungous attack.

The breaking strength of the 213 nodes tested ranged from a minimum of 6 pounds to a maximum of 330 pounds under the condition of the experiment. It is quite significant that the strength of the infected nodes is much lower than that of the uninfected ones. This relation of strength to infection is summarized in table 2.

TABLE 2.—*Pressure at which infected and uninfected nodes break*

	Node 1	Node 2	Node 3	Node 4	Node 5
Average of infected nodes	55	72	54	47	33
Average of uninfected nodes	163	133	104	84	64

In the above table it may be noted that the infected nodes have lost about one-half their strength, also that there is a gradual decrease in strength in progressing from the lower to the upper nodes. The upper nodes, however, are not subjected to the leverage of the wind that the lower part of the stalk must bear.

Histological study of the stalks reveals a greater degree of lignification in the lower nodes as illustrated in fig. 4. At first only the vascular bundles of the stem are lignified, but as the plant increases in age this lignification extends to the cellulose of the pith cells surrounding these until a thick sclerenchymatous area is formed on the outer periphery of the stalk. This extra lignification constitutes a very considerable layer up to the third and fourth nodes. Holbert and Koehler (3) have described a somewhat similar condition in the roots of different strains of corn in their relation to anchorage.

DISCUSSION

In tests of the nutritional relations of *Diplodia zeae, Gibberella saubinetti* and *Basisporium gallarum,* it was found that these organisms are capable of assimilating cellulose, and to a slight extent, lignin. Microchemical tests made on infected nodes also show the destruction of not only the cellulose connective tissue, but also the lignified fibers. This is in a degree comparable to the well-known effect of wood-destroying fungi whose solvent action on cellulose and lignin results in shrinkage and cracking of wood.

The disintegration of the tissues of the stalk (Fig. 3) results in ready breaking under strains that would be easily withstood by healthy stalks. Thus, high wind results in down corn after the nodal infection has progressed enough to weaken the stalks. In some fields this is very obvious for all the broken stalks point in the same general direction (Fig. 1). Pammel, King and Seal (4 and 5) found this condition in Iowa corn fields in 1914, but did not measure the effect or record the extent of nodal infection.

It is interesting in this connection to correlate the relation of wind velocity and pressure to the breaking strength of the stalks.

Taking, for example, the maximum velocity for September, 1923, 40 miles per hour, the given pressure per square foot amounts to 7.8 lbs. Further, for example, take an average cornstalk 10 ft. tall, measuring 1.25 inches in diameter at the base and .37 inches at the top. Such stalk would expose 97.2 sq. inches of surface to the wind, irrespective of leaves and ears. However, in September the leaves are largely torn away or badly frayed, making their resistance difficult to determine, so the stalk only will be considered. On the basis of a pressure of 7.8 pounds per sq. foot, a 10-foot stalk will receive 5.2 pounds of pressure distribution over its length.

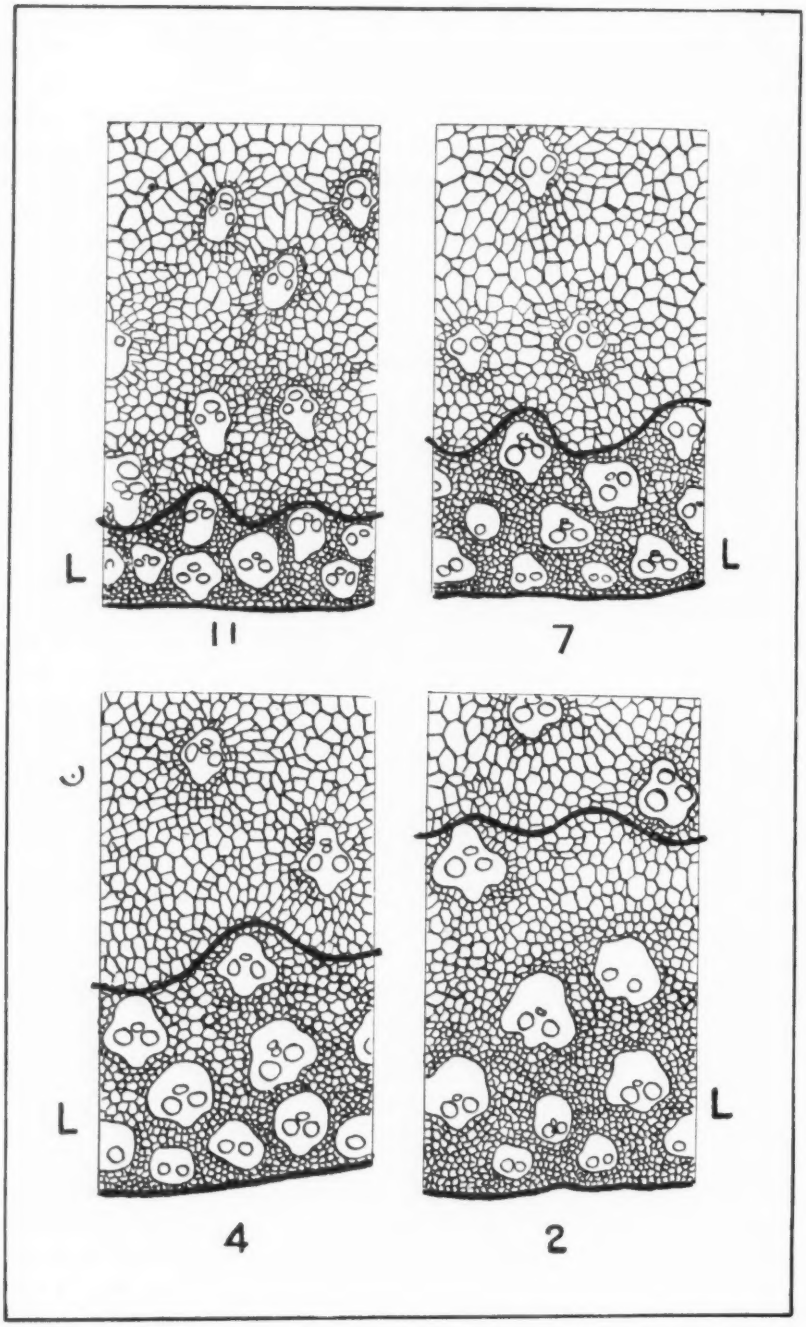

FIG. 4. Sections of corn stalk near second, fourth, seventh and eleventh nodes, showing the greater amount of lignification (L) at the lower nodes.

In determining the maximum stress induced in a section of a tapering cylinder, such as a cornstalk, the following formula might be used:

$$S' = \frac{32W\,(L - X)^2(d - KX)}{2\pi L\,((d - KX)^4 - (d' - K'X)^4)}$$

S′ — stress produced by wind
L — total length of stalk in inches
d — outer diameter of base in inches
d′ — inside diameter of base in inches
X — distance in inches of any section from base of stalk
K — decrease of outer diameter per inch in length
K′ — decrease of inner diameter per inch in length
W — total pressure due to wind
W′ — breaking load determined by breaking machine
L′ — distance between supports in breaking machine
S — stress produced in breaking machine.

The maximum stress, S, as determined by breaking the cornstalk in the above described machine, may be expressed in general by the formula

$$S = \frac{32W'L'd'}{\pi\,(d^4 - d'^4)}$$

With the use of these formulas, substituting known values from a representative stalk, it may be shown that it requires a 68-mile wind to break a healthy first node, while a 33-mile wind will break the average infected node.

Healthy third, fourth and fith nodes will be broken by 55-, 50-, and 34-mile winds, respectively, although the average infected third, fourth, and fifth nodes will break under 39-, 37-, and 24-mile winds, where the elasticity of the tissues is destroyed by fungi.

Under field conditions, as before stated, the leaves and ear furnish additional resistance, which would increase chances of breaking of infected nodes.

It might be argued that under such pressure all the tops of the stalks would break. It is obvious the same leverage is not exerted on the tops as on the lower parts of the stalk. Then, too, the topmost nodes are seldom infected, and so retain their elasticity. As shown by the writer (*l.c.*) in the case of *Diplodia zeae*, infection is most prevalent at the lower nodes because of the moister conditions nearer the ground and because the leaf sheaths first open there, allowing the entrance of organisms. Were it not for the greater lignification of the lowest nodes and the fact that the fungi under consideration attack lignin less readily than cellulose, these nodes

would break more commonly than those a little higher up as they receive the greatest strain.

SUMMARY

It has been observed during the past five years that in down corn the stalks are frequently broken at the fourth node or above.

Diplodia zeae, Gibberella saubinetti, Basisporium gallarum, and *Fusarium* sp. are prevalent on the broken stalks and weaken them by partially destroying the tissues at the nodes.

Infected nodes are not as strong as healthy ones according to the breaking tests recorded. A correlation exists between the breaking of the weakened nodes and the wind pressure exerted on the stalk.

The lower nodes are stronger than the upper ones, due to the greater lignification, which explains why the stalk more often breaks at or above the fourth node.

PLANT PATHOLOGICAL LABORATORIES,
IOWA AGRICULTURAL EXPERIMENT STATION,
AMES, IOWA.

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ALIQUOT FUSARIA TROPICALIA NOVA VEL REVISA[1]

H. W. WOLLENWEBER[2] AND O. A. REINKING[3]

INTRODUCTION

During an investigation conducted by the junior author on Fusaria in relation to various banana diseases in Central America, a large number of different strains of Fusaria were collected and studied. The fungi described in the paper comprise a limited number of new organisms, and revised forms of older species, that were found, out of some two hundred and fifty strains studied. In a few instances it was deemed necessary to revise and enlarge the descriptions of various sections and species for which only a meager or indefinite diagnosis existed. The descriptions have all been based upon pure culture studies carried on during the past two years, at first by the junior author and finally as a joint study by both authors. In the latter study access was had to all strains of Fusaria at present available in the United States and Europe.

In a study of the relation of Fusaria to plant diseases it is important to obtain a complete knowledge of all Fusaria present on plants and then to determine their pathogenicity. The first step in this procedure has been undertaken in a study of Fusaria in relation to banana diseases and the present number of new organisms were obtained. Their parasitic nature has not been determined. The majority belong to sections that include parasitic species and it is highly probable that further studies will prove the pathogenicity of a number of these. This is particularly true of those in section Liseola. One species in this section (*F. moniliforme*) is a common plant pathogen producing the kernel mold disease of corn; while the others are prevalent in the tropics associated with living and dead plants, and some apparently attack living tissue. In section Martiella, *F. theobromae* has been reported as causing a rot of cacao pods.

The systematic arrangement followed in the paper is according to the grouping of Fusaria into sections as given in a former article.[4]

Pure cultures of each species identified have been placed in the Pathological Collections of the Bureau of Plant Industry, United States Depart-

[1] Published as a contribution from the Agricultural Research Department, United Fruit Company, Boston, Mass.

[2] Pathologist, Biologische Reichsanstalt für Land und Forstwirtschaft.

[3] Pathologist, United Fruit Company.

[4] Wollenweber, H. W., Sherbakoff, C. D., and Reinking, O. A., with the cooperation of Johann, Helen and Bailey, Alice A. Fundamentals for taxonomic studies of Fusarium. Jour. Agr. Research 30: No. 2. 1925.

ment of Agriculture, and the Centraal-Bureau voor Schimmelcultures, Baarn, Holland.

DESCRIPTIONS OF NEW AND REVISED SECTIONS, SPECIES, VARIETIES AND FORMS

FUSARIUM Link

III. *Sectio Sporotrichiella* Wr.

Lewis, Charles E. 1913. Comparative studies of certain disease producing species of Fusarium. Maine Agr. Exp. Sta. Bul. 219, *p. 256.*

Sherbakoff, C. D. 1915. Fusaria of potatoes, N. Y. (Cornell) Agr. Exp. Sta. Mem. no. 6. *p. 183.*

Conidiis plerumque in aërium mycelium sparsis, pyriformibus vel globosis continuis, rarius septatis, sporodochiis deficientibus in speciebus typicis, macroconidiis raris, fusiformibus vel falcatis, septatis; chlamydosporis raris. Species: *F. poae* (Pck.) Wr., *F. sporotrichioides* Sherb., **F. chlamydosporum** n. sp.

Conidia for the most part scattered in the aerial mycelium, pyriform to globose, unicellular, sporodochia absent in typical species, macroconidia few, fusiform or sickle-shaped, septate; chlamydospores rare. Species *F. poae* (Pck.) Wr., *F. sporotrichioides* Sherb., **F. chlamydosporum** n. sp.

1. **Fusarium chlamydosporum** n. sp.

Microconidiis sparsis ad conidiophoros irregulariter ramosos dispositis, ovoideo-pyriformibus, plerumque continuis, 6–9 × 2.5–4.0 μ, raro 1-septatis, 11–16 × 3.0–3.5 μ; macroconidiis liberis, raris, falcatis, 1–3-septatis; 3-septatis, 27–32 × 3.5–4.5 μ; sporodochiis nullis; mycelio aerio floccoso, e roseo atropurpureo, e sulfureo ochraceo; stromate expanso vel erumpenti, tuberculari plectenchymico; chlamydosporis globosis vel pyriformibus, rugulosis, ochraceis, terminalibus vel intercalaribus, singulis, binis, catenulatis, acervalibus, 10–16 μ diam.

Habitat: Ad basim Musae sapientum (R38), humo aëreque, Honduras, Amer. centr. (O. A. Reinking no. R 38.)

Microconidia borne on irregularly branched conidiophores, ovoid, pyriform, mostly unicellular, 6–9 × 2.5–4.0 μ, rarely 1-septate, 11–16 × 3.0–3.5 μ; macroconidia scattered, rare, sickle-shaped, 1–3-septate; 3-septate, 27–32 × 3.5–4.5 μ; sporodochia not present; mycelium floccose from rose to carmine, from sulphuric to dark brown; plectenchymic stroma sometimes tubercular; chlamydospores globose to pear shaped, rugose to spiny, ochreous, terminal or intercalary, one to two celled, in chains or clusters, 10–16 μ in diameter.

Habitat: On the exterior of the pseudostem of a living banana plant (*Musa sapientum*) (R 38) also in the soil and in the air. Honduras, Central America. (O. A. Reinking no. R 38.)

Fusarium chlamydosporum n. sp. produces mostly microconidia of the sporotrichum type, a few sickle-shaped macroconidia and an abundance of large chlamydospores that are characteristic for the species. The aerial mycelium develops swellings, in some hyphae, that differ from chlamydospores in having no double wall. Such swellings are formed in *F. flocciferum* Cda. of the section Discolor, and in species of the section Gibbosum.

V. *Sectio Arthrosporiella* Sherb.

Sherbakoff, C. D. 1915. Fusaria of potatoes. N. Y. (Cornell) Agr. Exp. Sta. Mem. no. 6, *p. 161.*

Aërio mycelio abundante, albo-incarnato, sporodochiis et pionnote; microconidiis in aërio mycelio fusiformibus vel lanceolatis, apedicellatis, 0–3-septatis; macroconidiis in massis isabellinis vel ochraceis, falcatis, attenuatis, saepe pedicellatis, 3-pluriseptatis; chlamydosporis typicis intercalaribus, stromate ochraceo, castaneo, roseo, expanso, interdum nodoso acervali.

Aerial mycelium abundant, whitish to flesh color, sporodochia and pionnotes present; microconidia in aerial mycelium, spindle-shaped or lanceolate, apedicellate, 0–3-septate; macroconidia in masses, Isabella color or ochraceous, sickle-shaped, attenuate, often pedicellate, 3-more septate; chlamydospores typically intercalary, stroma ochraceous to chestnut-brown or rosy, spread out, sometimes selerotially erumpent.

2. *Fusarium semitectum* Berk. et Rav.

Berkeley, J. M. 1875. Notices of North American fungi. Grevillea **3**: *p. 98.*

Saccardo, P. A. 1886. Sylloge Fungorum **4**: *p. 718.*

Wollenweber, H. W. 1917. Fusaria autographice delineata. Ann. Mycol. **15**: *p. 11, fig. 112.*

Aërio mycelio albo-incarnato vel isabellino; stromate plectenchymico atro-ochraceo, interdum violaceo-carmineo; chlamydosporis intercalaribus; sporodochiis nullis; conidiis aërio mycelio instratis, fusiformibus, lanceolatis, subcurvatis, apedicellatis, appendiculatis, minoribus 0–2-septatis, maioribus 3–5–(6–7)-septatis; 0-septatis, 12 × 3.0–3.5 μ; 1-septatis, 11–21 × 2.5–4.5 μ; 2-septatis, 16–24 × 3.25–5.0 μ; 3-septatis, 18–40 × 3.0–5.5 μ; 4-septatis, 29–45 × 4.0–5.5 μ; 5-septatis, 36–52 × 4.0–5.5 μ; 6–7-septatis, 37–57 × 4.5–5.5 μ.

Habitat: Ad insertionem pistilli fructus putridi Lycopersici esculenti, in floribus emortuis, fructibus putridis, disco axis caesae Musae sapientum (R 50), in aëre, Honduras, Amer. centr. (O. A. Reinking no. R 50.)

Aerial mycelium white to flesh color or Isabella color, stroma plectenchymic, dark ochraceous sometimes violet-carmine; chlamydospores intercalary; sporodochia absent; conidia scattered in aerial mycelium, spindle-

shaped, lanceolate, slightly curved, apedicellate, appendicular, when smaller 0–2-septate, when larger 3–5–(6–7)-septate; 0-septate, 12 × 3.0–3.5 μ; 1-septate, 11–21 × 2.5–4.5 μ; 2-septate, 16–24 × 3.25–5.0 μ; 3-septate, 18–40 × 3.0–5.5 μ; 4-septate, 29–45 × 4.0–5.5 μ; 5-septate, 36–52 × 4.0–5.5 μ; 6–7-septate, 37–57 × 4.5–5.5 μ.

Habitat: At blossom end rot of tomato (*Lycopersicum esculentum*), in dead floral parts, decaying fruit and interior of pseudostem of diseased banana plant (*Musa sapientum*) (R 50), and in the air. Honduras, Central America. (O. A. Reinking no, R 50.)

Fusarium semitectum Berk. et Rav. is generally widespread throughout banana plantations, growing on the dead floral remains at the end of the individual banana fruits and decaying banana fruit and floral parts on the ground.

3. **Fusarium camptoceras** n. sp.

Aërio mycelio albo-incarnato vel isabellino; stromate atro-ochraceo interdum incarnato; chlamydosporis intercalaribus; sporodochiis nullis; conidiis aërio mycelio instratis, falcatis, utrinque subacutis, apice plus minusve constricto, basi rotundata vel conica, apedicellata interdum vero appendiculata, minoribus 0–2-septatis, maioribus 3–5–(6–7)-septatis; 0-septatis, 7–12 × 2.5–3.5 μ; 1-septatis, 11–18 × 3.0–4.0 μ; 2-septatis, 14–26 × 3.5–5.0 μ; 3-septatis, 17–32 × 3.5–5.5 μ; 4-septatis, 22–40 × 3.5–6.0 μ; 5-septatis, 29–52 × 4.5–6.0 μ; 6-septatis, 25–58 × 4.5–5.5 μ; 7-septatis, 31–51 × 4.0–5.5 μ.

Habitat: In fructibus putridis Musae sapientum, Theobromae cacao (R 78), in humo, Honduras, Amer. centr. (O. A. Reinking no. R 78.)

Aerial mycelium white to flesh color or Isabella color; stroma dark ochraceous sometimes flesh color; chlamydospores intercalary; sporodochia absent; conidia scattered in the aerial mycelium, sickle-shaped, slightly pointed at ends, more or less constricted at top end, rounded or conical at base, sometimes apedicellate, however, appendicular, smaller conidia 0–2-septate, larger conidia 3–5–(6–7)-septate; 0-septate, 7–12 × 2.5–3.5 μ; 1-septate, 11–18 × 3.0–4.0 μ; 2-septate, 14–26 × 3.5–5.0 μ; 3-septate, 17–32 × 3.5–5.5 μ; 4-septate, 22–40 × 3.5–6.0 μ; 5-septate, 29–52 × 4.5–6.0 μ; 6-septate, 25–58 × 4.5–5.5 μ; 7-septate, 31–51 × 4.0–5.5 μ.

Habitat: On decaying fruit of banana (*Musa sapientum*) and cacao (*Theobroma cacao*) (R 78), and in the soil. Honduras, Central America. (O. A. Reinking no. R 78.)

VI. *Sectio Gibbosum* Wr.

Wollenweber, H. W. 1913. Studies on the Fusarium problem. Phytopathology, 3, *p. 31, fig 1, L and M.*

Conidiis in sporodochiis et in pionnote, pallido ochraceis vel aurantiacis, dorsiventralibus falcatis, elliptice, parabolice vel hyperbolice curvatis, utrinque attenuatis, pedicellatis; interdum conidiis minoribus aerio mycelio instratis "commae" forma, 0–3-septatis, utrinque rotundatis vel leniter constrictis, apedicellatis; chlamydosporis intercalaribus; sclerotiis rarioribus interdum atro-coeruleis; stromate plectenchymico ochraceo, badio vel carmineo.

Conidia in sporodochia and in pionnotes, pale ochraceous to orange, dorsiventral sickle-shaped, elliptical, parabolical of hyperbolical curved, attenuate at both ends, pedicellate; sometimes smaller conidia in aerial mycelium, "coma" shaped, 0-3-septate, rounded at both ends or slightly constricted, apedicellate; chlamydospores intercalary; sclerotia rare, sometimes dark blue; stroma plectenchymic, ochraceous, chestnut-brown or carmine.

4. *Fusarium bullatum* Sherb.

Sherbakoff, C. D. 1915. Fusaria of potatoes. N. Y. (Cornell) Agr. Exp. Sta. Mem. no. 6, *p. 198*.

Auctore Sherbakoff hic fungus sub sectione Ferruginosa Sherb. descriptus est: conidiis falcatis, pedicellatis plerumque 5-septatis, 42 × 4.3 (31–47 × 4.1–4.9) μ, cremeis vel salmoneis; chlamydosporis intercalaribus, singulis, catenulatis vel acervalibus; stromate ex hyalino pallide luteolo tincto.

This fungus has been described by Sherbakoff under his section of Ferruginosum with sickle shaped, pedicellate, mostly 5-septate, 42 × 4.3 (31–47 × 4.1–4.9) μ, cream or salmon color conidia; chlamydospores intercalary, in chains or clusters; stroma from hyaline to pale golden.

5. *Fusarium bullatum* Sherb. var **minus** n. v.

A typo differt conidiis minoribus; conidiis in sporodochiis et in pionnote, pedicellatis, plerumque 3-septatis, 21–40 × 3.0–4.0 μ rarius 4-5-septatis; 5-septatis, 33–42 × 3.5–4.5 μ; conidiis aerio mycelio instratis interdum subnormibus apedicellatis, 3(1–5)-septatis.

Habitat: In partibus putridis plantae ignotae in insula Jamaica (C. G. Hansford no. 14, R 233).

Differs from the type species by smaller conidia; conidia in sporodochia or in pionnotes, pedicellate, mostly 3-septate, 21–40 × 3.0–4.0 μ; seldom 4-5-septate; 5-septate, 33–42 × 3.5–4.5 μ; conidia in aerial mycelium sometimes subnormal apedicellate, 3(1–5)-septate.

Habitat: In plant debris. Jamaica (C. G. Hansford no. 14, R 233). The fungus was obtained through the courtesy of Mr. C. G. Hansford of Jamaica.

6. *Fusarium bullatum* Sherb. var. **brevius** n. var.

A typo differt conidiis brevioribus 5(3–5)-septatis; 5-septatis, 31–44 × 3.0–4.0 μ; 3-septatis, 21–36 × 2.5–3.5 μ.

Habitat: In ramis emortuis Hybisci rosae-sinensis, in foliis aliisque partibus Musae sapientum (R 47), Honduras, Amer. centr. (O. A. Reinking no. R 47.)

Differs from the type species by shorter conidia, 5(3–5)-septate; 5-septate, 31–44 × 3.0–4.0 μ; 3-septate, 21–36 × 2.5–3.5 μ.

Habitat: On dead hibiscus stems (*Hibiscus rosa-sinensis*), decaying banana leaves and plant parts (*Musa sapientum*) (R 47). Honduras, Central America. (O. A. Reinking no. R 47.)

7. **Fusarium longipes** n. sp.

Stromate expanso vel erumpente verrucosa, aerio mycelio ex albo carmineo et ochraceo; conidiis in sporodochiis et in pionnote, interdum in columnis dispositis, ochraceo-aurantiacis, elongatis falcatis, parabolice vel hyperbolice curvatis attenuatis, apice procero plus minusve voluto, basi distincte longipedicellata; 5(4–6)-septatis, 63–104 × 2.75–4.0 μ; conidiis minoribus aerio mycelio instratis brevipedicellatis; 5-septatis, 36–53 × 3.0–4.0 μ; chlamydosporis subverrucosis, intercalaribus, plerumque singulis, 6–9 μ diam.

Habitat: Ad folia matura viventia Musae sapientum, Honduras, Amer. centr. (O. A. Reinking no. R 34.)

Stroma spread out or verrucose erumpent, aerial mycelium from white to carmine and ochraceous; conidia in sporodochia and in pionnotes, sometimes in columns, ochraceous to orange, elongate sickle-shaped, parabolically or hyperbolically curved, attenuate with whip-like top end sometimes very much curved, footed basal cell long, 5(4–6)-septate, 63–104 × 2.75–4.0 μ; smaller conidia in aerial mycelium with a short footed base; 5-septate, 36–53 × 3.0–4.0 μ; chlamydospores sometimes spiney, subverrucose, intercalary, mostly singular, 6–9 μ diameter.

Habitat: On mature and living leaves of banana (*Musa sapientum*). Honduras, Central America. (O. A. Reinking no. R 34.)

VII. *Sectio Roseum* Wr.

Wollenweber, H. W. 1918. Conspectus analyticus Fusariorum. Berichte der Deut. Bot. Gessell. 35: *p. 739.*

8. *Fusarium anthophilum* (A. Br.) Wr.

(Syn. *Fusisporium anthophilum* A. Braun.)

Braun, A. 1875. In Rabenhorst Fungi Europaei. no. 1964.

3.25 μ; 6-septatis, 61–92 × 2.5–3.25 μ: microconidiis catenulatim dispositis continuis, 4–16 × 2.0–4.0 μ, rarius 1-septatis, 14–21 × 2.5–3.5 μ; chlamydosporis nullis; sclerotiis atrocoeruleis.

Habitat: Ad pedunculos fructus, folia emortua Musae sapientum, Honduras, Amer. centr. (O. A. Reinking no. R 57.)

Differs from the type by longer macronconidia, 3-5-(6)-septate; 3-septate, 28–48 × 2.25–3.5 μ; 4-septate, 44–64 × 2.25–3.25 μ; 5-septate, 54–76 × 2.5–3.25 μ; 6-septate, 61–92 × 2.5–3.25 μ; microconidia in chains, unicellular, 4–16 × 2.0–4.0 μ; rarely 1-septate, 14–21 × 2.5–3.5 μ; chlamydospores absent; sclerotia dark blue.

Habitat: On dead peduncles and leaves of banana (*Musa sapientum*). Honduras, Central America. (O. A. Reinking no. R 57.)

13. **Fusarium neoceras** n. sp.

Microconidiis liberis vel in capitulis falsis, non in catenulis dispositis, continuis ovoideo fusoideis, 9–12 × 3.0–3.5 (5–18 × 2.75–4.5)μ; rarius 1-septatis, 19–26 × 3.5–4.5 (14–34 × 3.25–5.5)μ; macroconidiis in sporodochiis, plerumque vero in pionnote, elongatis subcurvatis, attenuatis, subpedicellatis, apice vix constrictis, 3–5-septatis, 38–68 × 4.0–5.0 (30–95 × 3.5–5.5)μ; 3-septatis, 32–59 × 3.0–5.5 μ; 4-septatis, 30–63 × 4.0–5.5 μ; 5-septatis, 55–67 × 4.5–5.5 μ, rarissimis 6–9-septatis, 67–120 × 4.0–5.0 μ; chlamydosporis et sclerotiis nullis; stromate interdum violaceo.

Habitat: In bracteis emortuis Musae sapientum et in humo, Honduras, Amer. centr. (O. A. Reinking no R 149.)

Microconidia scattered or in false heads, not in chains, unicellular ovoid fusoid, 9–12 × 3.0–3.5 (5–18 × 2.75–4.5)μ; rarely 1-septate, 19–26 × 3.5–4.5 (14–34 × 3.25–5.5)μ; macroconidia in sporodochia, but mostly in pionnotes, elongate, slightly curved, attenuate, subpedicellate, slightly constricted at the top, 3-5-septate, 38–68 × 4.0–5.0 (30–95 × 3.5–5.5)μ; 3-septate, 32–59 × 3.0–5.5 μ; 4-septate, 30–63 × 4.0–5.5 μ; 5-septate, 55–67 × 4.5–5.5 μ; very seldom 6-9-septate, 67–120 × 4.0–5.0 μ; chlamydospores and sclerotia absent; stroma sometimes violet.

Habitat: On dead floral bracts of banana (*Musa sapientum*) (R 149) and in soil. Honduras, Central America. (O. A. Reinking no. R 149.)

The various strains of Liseola herein described are widespread throughout banana plantations, being present on decaying plant trash of different kinds and on living parts of plants. The parasitic nature of the different strains has not been carefully tested.

IX. *Sectio Lateritium* Wr.

Wollenweber, H. W. 1917. Fusaria autographice delineata, Ann. Mycol. **15**: *p. 54.*

Wollenweber, H. W. 1917. Fusaria autographice delineata. Ann. Mycol. 15: *p. 14, fig. 176–177.*

Stromate pallido, nunquam carmineo; conidiis liberis, in pionnote, rarius in sporodochiis, subulatis vel falcatis, Fusario herbarum similibus, pedicellatis, 3-5-septatis, 35–70 × 2.5–4.0 (30–82 × 2.5–4.5)μ; rarissime 6-pluriseptatis; conidiis liberis lanceolatis vel subcurvatis, utrinque attenuatis, apedicellatis vel appendiculatis; chlamydosporis nullis.

Habitat: In corollis et antheris Succisae pratensis, quae corollae clausae manent, mox arescunt et putrescunt, Berchtesgaden Bavaria in Germania (A. Braun). In inflorescentiis emortuis Citri aurantifoliae, foliis aridis Dauci carotae, pedunculis fructuum, foliis aliisque partibus emortuis Musae sapientum, legumine maturo Phaseoli vulgaris, ramis siccis Theobromae cacao (R 97), in humo aëreque, Honduras, Amer. centr. (O. A. Reinking no. R 97.)

Stroma pale, never carmine, conidia scattered, in pionnotes seldom in sporodochia, slender, attenuate at both ends, sickle-shaped, similar to *Fusarium herbarum*, pedicellate, 3-5-septate, 35–70 × 2.5–4.0 (30–82 × 2.5–4.5)μ; rarely 6-more septate, scattered conidia lanceolate, slightly curved, attenuate at both ends, apedicellate or appendicular; chlamydospores absent.

Habitat: In prematurely dead and rotting inflorescences of *Succisa pratensis.* In Berchtesgaden, Bavaria, Germany. (A. Braun.) On dead inflorescence of Rangphur lime (*Citrus aurantifolia*), on dead leaves of carrot (*Daucus carota*), on decaying peduncle and plant trash of banana (*Musa sapientum*), on dried pod of bush bean (*Phaseolus vulgaris*), on dead cacao twigs (*Theobroma cacao*) (R 97), and in soil and air. Honduras, Central America. (O. A. Reinking no. R 97.)

Fusarium anthophilum (A. Br.) Wr. is common on decaying and dead parts of various hosts. It can also be quite generally isolated from soil and air.

VIII. *Liseola Wr., Sherb., Rkg., Joh., et Bail.*

(Syn.. sect. Moniliforme Sherb.; subsect. Constrictum Wr.; pro parte sectionis Elegantis Wr.) Wollenweber, H. W., Sherbakoff, C. D., and Reinking, O. A., with the cooperation of Johann, Helen and Bailey, Alice A. 1924. Fundamentals for taxonomic studies of Fusarium. In Jour. Agr. Research 30: No. 2., 1925.

Microconidiis plus minusve in catenulis dispositis fusiodeo-ovoideis; macroconidiis subulatis, apice constrictis, basi pedicellata, forma et colore sectionis Lateritii, liberis, in sporodochiis, in pionnote, ochroleucis vel aurantiaco-cinnabarinis; chlamydosporis nullis; stromate expanso, ex albo

violaceo vel sclerotiis coeruleis erumpente. Status conidicus Gibberellae sectionis Liseae (Sacc.) Wr.

Microconidia more or less formed in chains, spindle to ovoid in shape; macroconidia slender with a slightly constricted top end, and a pedicellate base. Form and color similar to section Lateritium, scattered, in sporodochia or in pionnotes, brownish-white to orange-cinnamon; chlamydospores absent; stroma white to violet, spread out or erumpent, sometimes with blue sclerotia. Conidial stage of Gibberella section Liseae (Sacc.) Wr.

9. *Fusarium moniliforme* Sheld.

Sheldon, J. L. 1904. A corn mold (*Fusarium moniliforme*, n. sp.). Nebr. Agr. Exp. Sta., Ann Rpt., 1903, **17**: 23–32, illus.

Saccardo, P. A. 1913. Sylloge Fungorum **22**: *p. 1485.*

Wollenweber, H. W. 1917. Fusaria autographice delineata. Ann. Mycol. **15**: *p. 23, fig. 366.*

Microconidiis catenulatim vel in capitulis falsis dispositis aerio mycelio albido-isabellino instratis, fusoideo-ovoideis, 5–12 × 2.25–4.0 μ; macroconidiis tenuibus subulatis, falcatis, attenuatis, pedicellatis, liberis, in sporodochiis, in pionnote, ochroleucis vel aurantiaco-cinnabarinis, plerumque 3-septatis, 30–36 × 3.0–3.5 (23–48 × 2.25–4.0) μ, rarius 1-, 4-, 5-septatis; 1-septatis, 12–18 × 2.25–3.5 μ; 4-septatis, 37–53 × 3.0–3.5 μ; 5-septatis, 43–66 × 3.0–3.5 μ; chlamydosporis nullis; sclerotiis coeruleis usque ad 0.5 mm. diam., stromate violaceo vel ochraceo.

Habitat: In caryopsidibus Zeae maydis aegrotis in Amer. bor. (Sheldon), in Honduras, Amer. centr. (O. A. Reinking, no. R 73), in foliis, intra truncum falsum maturum, in ramos floriferos emortuos Musae sapientum (R 53), in plantis indeterminates putridis, in humo aëreque, Honduras, Amer. centr. (O. A. Reinking no. R 53 et R 73), in foliis putrescentibus Ananassae sativae in insula Jamaica (C. G. Hansford no. 5, R 225).

Microconidia in chains or in false heads, formed in white to Isabella color aerial mycelium, spindle to ovoid in shape, 5–12 × 2.25–4.0 μ; macroconidia delicate and slender, sickle-shaped, attenuate, pedicellate, scattered or in sporodochia or pionnotes, brownish-white to orange-cinnamon; mostly 3-septate, 30–36 × 3.0–3.5 (23–48 × 2.25–4.0) μ, fewer 1-, 4-, 5-septate; 1-septate, 12–18 × 2.25–3.5 μ; 4-septate, 37–53 × 3.0–3.5 μ; 5-septate, 43–66 × 3.0–3.5 μ; chlamydospores absent; sclerotia blue, 0.5 mm. diam.; stroma violet or ochraceous.

Habitat: On diseased kernels of corn (*Zea mays*) in North America (Sheldon) and in Honduras, Central America (O. A. Reinking no. R 73), on leaves, in interior of diseased pseudostem and on dead floral parts (R 53) of banana (*Musa sapientum*), on decaying undetermined plant, and in soil and air. Honduras, Central America. (O. A. Reinking no. R 53 and R 73.)

On rotting bud leaves of pineapple (*Ananas sativus*). Jamaica. (C. G. Hansford no. 5, R 225.)

10. *Fusarium moniliforme* Sheld. var **erumpens** n. var.

A typo differt pluribus sclerotiis maioribus rugulosis atrocoeruleis modo Gibberellae acervatim erumpentibus; microconidiis catenulatim dispositis; macroconidiis plerumque 3-5-septatis; 3-septatis, 22–48 × 2.5–3.5 μ; 4-septatis, 33–47 × 3.25–3.5 μ; 5-septatis, 33–51 × 3.25–3.5 μ; chlamydosporis nullis.

Habitat: In disco trunci falsi vivnetis caesi Musae sapientum, Honduras, Amer. centr. (O. A. Reinking no. R 62.)

Differs from the type by having more and larger rugose, dark blue sclerotia, erumpent and clustered Gibberella like; microconidia in chains; macroconidia mostly 3-5-septate; 3-septate, 22–48 × 2.5–3.5 μ; 4-septate, 33–47 × 3.25–3.5 μ; 5-septate, 33–51 × 3.25–3.5 μ; chlamydospores absent.

Habitat: In vascular bundles of living, diseased pseudostem of banana (*Musa sapientum*). Honduras, Central America. (O. A. Reinking no. R 62.)

11. *Fusarium moniliforme* Sheld. var. **subglutinans** n. var.

A typo differt praesertim microconidiis non in catenulis dispositis; microconidiis continuis, 6–15 × 2.0–3.5 μ, macroconidiis plerumque 3-septatis, 21–38 × 3.0–3.5 (18–50 × 2.75–4.0) μ; rarius 1-septatis, 10–25 × 2.5–3.5 μ; 4-septatis, 27–50 × 3.25–4.0 μ; interdum 5-septatis, 43–55 × 3.25–4.0 μ; 6-7-septatis, 48–57 × 3.25–4.0 μ; chlamydosporis nullis; sclerotiis atrocoeruleis.

Habitat: In foliis et trunco falso putridis, in vascularibus fasciculis et ad superficiem trunci falsi viventis Musae sapientum, in aëre, Honduras, Amer. centr. (O. A. Reinking no. R 60.)

Differs from the type principally in having the microconidia not borne in chains; microconidia unicellular, 6–15 × 2.0–3.5 μ; macroconidia mostly 3-septate, 21–38 × 3.0–3.5 (18–50 × 2.75–4.0) μ; fewer 1-septate, 10–25 × 2.5–3.5 μ; 4-septate, 27–50 × 3.25–4.0 μ; sometimes 5-septate, 43–55 × 3.25–4.0 μ; 6-7-septate, 48–57 × 3.25–4.0 μ; chlamydospores absent; sclerotia dark blue.

Habitat: On decaying leaves and pseudostem, in the vascular bundles and exterior of living pseudostem of banana (*Musa sapientum*), and in the air. Honduras, Central America. (O. A. Reinking no. R 60.)

12. *Fusarium moniliforme* Sheld. var. **maius** n. var.

A typo differt macroconidiis longioribus, 3-5-(6)-septatis; 3-septatis, 28–48 × 2.25–3.5 μ; 4-septatis, 44–64 × 2.25–3.25 μ; 5-septatis, 54–76 × 2.5–

3.25 μ; 6-septatis, 61–92 × 2.5–3.25 μ: microconidiis catenulatim dispositis continuis, 4–16 × 2.0–4.0 μ, rarius 1-septatis, 14–21 × 2.5–3.5 μ; chlamydosporis nullis; sclerotiis atrocoeruleis.

Habitat: Ad pedunculos fructus, folia emortua Musae sapientum, Honduras, Amer. centr. (O. A. Reinking no. R 57.)

Differs from the type by longer macronconidia, 3-5-(6)-septate; 3-septate, 28–48 × 2.25–3.5 μ; 4-septate, 44–64 × 2.25–3.25 μ; 5-septate, 54–76 × 2.5–3.25 μ; 6-septate, 61–92 × 2.5–3.25 μ; microconidia in chains, unicellular, 4–16 × 2.0–4.0 μ; rarely 1-septate, 14–21 × 2.5–3.5 μ; chlamydospores absent; sclerotia dark blue.

Habitat: On dead peduncles and leaves of banana (*Musa sapientum*). Honduras, Central America. (O. A. Reinking no. R 57.)

13. **Fusarium neoceras** n. sp.

Microconidiis liberis vel in capitulis falsis, non in catenulis dispositis, continuis ovoideo fusoideis, 9–12 × 3.0–3.5 (5–18 × 2.75–4.5)μ; rarius 1-septatis, 19–26 × 3.5–4.5 (14–34 × 3.25–5.5)μ; macroconidiis in sporodochiis, plerumque vero in pionnote, elongatis subeurvatis, attenuatis, subpedicellatis, apice vix constrictis, 3–5-septatis, 38–68 × 4.0–5.0 (30–95 × 3.5–5.5)μ; 3-septatis, 32–59 × 3.0–5.5 μ; 4-septatis, 30–63 × 4.0–5.5 μ; 5-septatis, 55–67 × 4.5–5.5 μ, rarissimis 6–9-septatis, 67–120 × 4.0–5.0 μ; chlamydosporis et sclerotiis nullis; stromate interdum violaceo.

Habitat: In bracteis emortuis Musae sapientum et in humo, Honduras, Amer. centr. (O. A. Reinking no R 149.)

Microconidia scattered or in false heads, not in chains, unicellular ovoid fusoid, 9–12 × 3.0–3.5 (5–18 × 2.75–4.5)μ; rarely 1-septate, 19–26 × 3.5–4.5 (14–34 × 3.25–5.5)μ; macroconidia in sporodochia, but mostly in pionnotes, elongate, slightly curved, attenuate, subpedicellate, slightly constricted at the top, 3-5-septate, 38–68 × 4.0–5.0 (30–95 × 3.5–5.5)μ; 3-septate, 32–59 × 3.0–5.5 μ; 4-septate, 30–63 × 4.0–5.5 μ; 5-septate, 55–67 × 4.5–5.5 μ; very seldom 6-9-septate, 67–120 × 4.0–5.0 μ; chlamydospores and sclerotia absent; stroma sometimes violet.

Habitat: On dead floral bracts of banana (*Musa sapientum*) (R 149) and in soil. Honduras, Central America. (O. A. Reinking no. R 149.)

The various strains of Liseola herein described are widespread throughout banana plantations, being present on decaying plant trash of different kinds and on living parts of plants. The parasitic nature of the different strains has not been carefully tested.

IX. *Sectio Lateritium* Wr.

Wollenweber, H. W. 1917. Fusaria autographice delineata, Ann. Mycol. **15**: *p. 54.*

F. fructigenum Fr.

Fries, E. 1829. Syst. Myc. **3**: *p. 471.*

Saccardo, P. A. 1886. Sylloge Fungorum **4**: *p. 717.*

Wollenweber, H. W. 1917. Fusaria autographice delineata. Ann. Mycol. **15**: *p. 19, fig. 281–285.*

Wollenweber, H. W. 1918. Conspectus analyticus Fusariorum. Berichte der Deut. Bot. Gesell. **35**: *p. 740.*

14. *Fusarium fructigenum* Fr. var. *maius* Wr. forma 1 n. f.

Conidiis in sporodochiis et in pionnote, aurantiacis, fusoideo-falcatis, apicem versus conspicue inaequilatere et magis curvatis quam ad medium, utrinque constrictis atque adeo pedicellatis ad basim, 5(3–6)-septatis; 5-septatis, 48–64 × 3.5–4.5 μ; 6-septatis, 63–80 × 3.5–4.75 μ; 3-septatis, 34–44 × 3.5–4.5 μ; chlamydosporiis raris, sclerotiis (½ mm. diam.) atrocoeruleis vel ochroleucis; stromate carmineo. A typo differt colore carmineo stromatis.

Habitat: In planta ignota emortua, in insula Jamaica. (C. G. Hansford no. 16, R 235.)

Conidia in sporodochia and pinnotes, orange, spindle to sickle-shaped, dorsi-ventral difference in curvature more conspicuous towards the top cell than in the middle, constricted at both ends or even pedicellate at the base, 5(3–6)-septate; 5-septate, 48–64 × 3.5–4.5 μ; 6-septate, 63–80 × 3.5–4.75 μ; 3-septate, 34–44 × 3.5–4.5 μ; chlamydospores seldom present; sclerotia (½ mm. diam.) dark blue or ochraceous white; stroma carmine. Differs from the type by carmine color of the stroma.

Habitat: On undetermined dead plant. Jamaica. (C. G. Hansford no. 16, R. 235.)

The culture was obtained through the courtesy of Mr. C. G. Hansford of Jamaica.

XII. *Sectio Saubinetii* Wr.

Wollenweber, H. W. 1917. Fusaria autographice delineata. Ann. Mycol. **15**: *p. 2.*

Stromate expanso floccoso vel plectenchymico, flavo-ochraceo, carmineo, mycelio aerio ex albo roseo intertexto; conidiis liberis, in sporodochiis, in pionnote, e pallide aurantiaco ochraceis, falcatis, elongatis, 3-pluriseptatis, apice rostrato, basi pedicellata vel—statu subnormi—apedicellata; chlamydosporis nullis. Aliquot species generi Gibberellae, sect. Saubinetii tribuendae.

Stroma spread out, floccose or dense, ochraceous, carmine, aerial mycelium from white to rose color; conidia scattered, in sporodochia or

in pionnotes, from pale orange to ochraceous, sickle-shaped, elongate, 3-more septate, constricted at top end, pedicellate at base, sometimes apedicellate; chlamydospores absent. Some species have a perfect stage that is a Gibberella of section Saubinetii.

15. **Fusarium macroceras** n. sp.

Stromate floccoso ex albo roseo vel plectenchymico, flavo, ochraceo, carmineo; conidiis liberis lanceolatis vel subfalcatis, dorsiventralibus, ad apicem rostratis, ad basim conicis, apedicellatis; conidiis in sporodochis et in pionnote elongatis, subfalcatis, utrinque attenuatis pedicellatis, 5-7-septatis, 47–64 × 4.5–5.75 (35–74 × 4.0–7.0) μ, rarius 1-4-vel 8-9-septatis, rarissime 14-septatis, 150 × 625 μ; chlamydosporis nullis.

Habitat: In leguminibus maturis Phaseoli vulgaris, Honduras, Amer. centr. (O. A. Reinking no. R 95.)

Stroma floccose, rosy white, or dense plectenchymic, yellow, ochraceous, and carmine. Conidia scattered, lanceolate or sickle-shaped, dorsi-ventral, constricted at the top end, conical at the base, apedicellate; conidia in sporodochia and pionnotes, elongate, slightly sickle-shaped, attenuated at both ends, pedicellate, 5-7-septate, 47–64 × 4.5–5.75 (35–79 × 3.5–7.0) μ, fewer 1-4- or 8-9-septate, very seldom 14-septate, 130 × 6.25 μ; chlamydospores absent.

Habitat: On mature bush bean pods (*Phaseolus vulgaris*). Honduras, Central America. (O. A. Reinking no. R 95.)

XIII. *Sectio Elegans* Wr.

Wollenweber, H. W. 1913. Studies on the Fusarium problem. Phytopathology **3**: *p. 28.*

Wollenweber, H. W. 1918. Conspectus analyticus Fusariorum. Berichte der Deut. Bot. Gesell. **35**: *p. 741.*

Subsectio Orthocera Wr.

Wollenweber, H. W. 1917. Fusaria autographice delineata. Ann. Mycol. **15**: *p. 2.*

Wollenweber, H. W. 1918. Conspectus analyticus Fusariorum. Berichte der Deut. Bot. Gessell. **35**: *p. 741.*

16. **Fusarium bostrycoides** n. sp.

Stromate plectenchymico ex ochroleuco viridi vel violaceo; aërio mycelio caespitoso flavido albo; microconidiis numerosis, instratis vel in capitulis falsis ad conidiophoros verticellate et bostryce ramosos dispositis, continuis, ovoideis, 6–11 × 2.5–3.24 (4–13 × 2.0–4.0) μ, rarissimis 1-septate, 15–22 ×

2.5–3.75 μ, 3-septatis orthoceris vel leniter falcatis, subpedicellatis, 24–29 × 2.5–4.0 μ; sporodochiis et pionnote deficientibus; chlamydosporis numerosis terminalibus et intercalaribus, globosis, singulis, vel catenulatis, rugulosis, 6–8 μ diam.

Habitat: In humo, Honduras, Amer. centr. (O. A. Reinking no. R 169.)

Observatio: Fungus ad pultem Oryzae coctae cultus colorem roseum acidum secernit, cuius modificatio alcalina coerulea est.

Stroma plectenchymic from brownish white to green or violet; aerial mycelium caespitose, cream color; microconidia, numerous, scattered or in false heads, formed on verticillate or bostrix-like branched conidiophores; unicellular, ovoid, 6–11 × 2.5–3.25 (4–13 × 2.0–4.0) μ; very rarely 1-septate, 15–22 × 2.5–3.75 μ, and 3-septate, straight to slightly sickle-shaped, subpedicellate, 24–29 × 2.5–4.0 μ; sporodochia and pionnotes absent; chlamydospores numerous, terminal and intercalary, globose, unicellular or in chains, rugose, 6–8 μ diam.

Habitat: In soil, Honduras, Central America. (O. A. Reinking no. R 169.)

Note: Fungus on rice culture with rosy acid modification of color, changing to blue by addition of sufficient alkali.

XIV. *Sectio Martiella* Wr.

Wollenweber, H. W. 1913. Studies on the Fusarium problem. Phytopathology **3**: *p. 30.*

Wollenweber, H. W. 1918. Conspectus analyticus Fusariorum. Berichte der Deut. Bot. Gesell. **35**: *p. 738.*

17. **Fusarium alluviale** n. sp.

Stromate erumpente ruguloso badio vel aerugineo tincto; conidiis dorsiventralibus fusoideo-falcatis, apice truncate rostrato, basi subpedicellata, in sporodochiis, in pionnote vel liberis, in massis ex albo badiis, 3-septatis, 29–34 × 4.25–5.5 (25–44 × 4.0–6.25) μ; rarius 4-septatis, 32–43 × 4.0–6.0 μ; in aërio mycelio conidiis minoribus quoque, continuis, 9–14 × 3.0–4.5 μ, et 1-septatis, 15–25 × 4.0–5.25 μ; chlamydosporis terminalibus et intercalaribus, interdum spinosis, in mycelio et in conidiis, plerumque continuis, 6–11 μ diam. Fungus in variis substratis cultis gravem odorem reddit.

Habitat: In humo alluviali, Honduras, Amer. centr. (O. A. Reinking no. R 188.)

Stroma erumpent, rugose, greenish blue; conidia dorsiventral, spindle to sickle shaped, top cell beak shaped, basal cell slightly pedicellate, in sporodochia, in pionnotes or scattered, in masses from white to chestnut-brown; 3-septate, 29–34 × 4.25–5.5 (25–44 × 4.0–6.25) μ; seldom 4-septate, 32–43 × 4.0–6.0 μ; in aerial mycelium smaller conidia also present, unicellular,

9–14 × 3.0–4.5 μ, and 1-septate, 15–25 × 4.0–5.25 μ; chlamydospores terminal, intercalary, sometimes spiney, in mycelium and in conidia, mostly unicellular, 6–11 μ dia. Strong odor produced on various culture media.

Habitat: In alluvial soil. Honduras, Central America. (O. A. Reinking no. R 188.)

18. *Fusarium theobromae* App. et Strk.

(Syn. *Fusarium heveae* P. Henn.)

Appel, O, and Strunk, H. F. 1904. Uber einige in Kamerun auf Theobroma cacao beobachtete Pilze. Centralbl. f. Bakt. u Par. etc. Abt. II. 11: 551–557, 632–637.

Wollenweber, H. W. 1917. Fusaria autographice delineata. Ann. Mycol. 15: *p. 26, fig. 426–428.*

Stromate plectenchymico ochroleuco interdum olivaceo vel aeruginoso; aërio mycelio ex albo cremeo intricato, caespitoso; conidiis plerumque sparsis interdum in sporodochiis et in pionnote, cremeis, elongatis leniter incurvatis, 3–5-septatis; 3-septatis; 28–46 × 3.5–5.0 μ; 5-septatis, 44–60 × 4.0–5.5 μ; rarissime 6-septatis, 52–73 × 4.5–5.5 μ,[5] in aërio mycelio quoque minoribus plus minusve continuis, ovoideis, 6–12 × 2.5–3.5 μ; chlamydosporis globosis vel pyriformibus, terminalibus et intercalaribus, singulis, binis, acervalibus, 5–8 μ diam.

Habitat: In fructibus seminibusque putridis Theobromae cacao, in horto botanico Victoriae Camerun Africae occid. (Strunk), ramis emortuis Heveae brasiliensis, Ceylon, Indiae, radice Manihotis utilissimae, Java; et in humo, Honduras, Amer. centr. (O. A. Reinking no. R 129.)

Stroma plectenchymic, ochraceous white, sometimes olive to greenish blue; aerial mycelium cream white, caespitose; conidia mostly scattered, more seldom in sporodochia, cream color in masses, elongate, slightly curved, 3–5-septate; 3-septate, 28–46 × 3.5–5.0 μ; 5-septate, 44–60 × 4.0–5.5 μ; very rarely 6-septate, 52–73 × 4.5–5.5 μ;[6] in aerial mycelium also smaller conidia, mostly unicellular ovoid, 6–12 × 2.5–3.5 μ; chlamydospores globose or pear shaped, terminal and intercalary, one celled, two celled or in clusters, 5–8 μ diam.

Habitat: On rotted fruits and kernels of cacao (*Theobroma cacao*) in botanical gardens Victoria, Camerun, Western Africa (Strunk); dead branches of Hevea rubber (*Hevea brasiliensis*) Ceylon, India; roots of cassava (*Manihot utilissima*) Java, and in soil, Honduras, Central America. (O. A. Reinking no. R 129.)

[5] Conidia in diagnosi sec. Appel et Strunk pluri-septata, 45–75 × 5.0–7.0 μ; conferas vero conidia in Wollenweber, Fus. del. 428, 4–6 (3–7)-septata, 39–60 × 4.5–5.25 μ.

[6] Conidia according to the diagnosis of Appel and Strunk are described as pluriseptate, 45–75 × 5–7 μ, while according to Wollenweber, in Fus. del. 428, they are 4–6 (3–7)-septate, 39–60 × 4.5–5.25 μ.

19. **Fusarium ensiforme** n. sp.

Stromate erumpente sclerotiali rugoso saepe atrocoeruleo; conidiis in sporodichiis et in pionnote ex albo aureo-ochraceis, elongatis subfalcatis, apice leniter constricto, basi conspicue pedicellata, 5–6(3–7)-septatis, 55–72 × 4.5–5.0 μ; 7-septatis, 69–81 × 4.75–5.0 μ; 4-septatis, 43–60 × 4.0–5.0 μ; 3-septatis, 37–50 × 3.75–5.0 μ; in aërio myceelio quoque minoribus, plerumque continuis ovoideis vel subcurvatis, 5–12 × 2.5–4.0 μ; chlamydosporis terminalibus vel intercalaribus, singulis vel binis, interdum rugosis, 6–9 μ diam.

Habitat: Ad fructus putridos Fici spec. ignotae arboris procerae tropicalis, in silva nativa. Honduras Amer. centr. (O. A. Reinking no. R 88.)

Stroma erumpent, sclerotial rugose, often dark blue; conidia in sporodochia and in pionnotes, from whitish to golden yellow, elongate, slightly sickle shaped, somewhat constricted at the top end, distinctly pedicellate at the base, 5–6 (3–7)-septate, 55–72 × 4.5–5.0 μ; 7-septate, 69–81 × 4.75–5.0 μ; 4-septate, 43–60 × 4.0–5.0 μ; 3-septate, 37–50 × 3.75–5.0 μ; in aerial mycelium also smaller, mostly unicellular, ovoid or slightly curved, 5–12 × 2.5–4.0 μ; chlamydospores terminal or intercalary, one- or two-celled, sometimes rugose, 6–9 μ diam.

Habitat: On decaying fruit of wild fig (*Ficus* sp.) in virgin forest. Honduras, Central America. (O. A. Reinking no. R 88.)

CONCLUSION

The general type of macroconidia, which was regarded as the most important character in former taxonomy of Fusaria, has now been proved to be more valuable in connection with other characters, such as the presence of microconidia, chlamydospores, and sporodochial or pionnotal production. The newly established section of Liseola has certain characters which distinguish it from other related sections. It could only be separated from section Lateritium by having microconidia which in general are absent in the latter. Section Elegans has chlamydospores that are not produced in section Liseola. The separation from section Roseum is based partially on a tendency to a constriction of the top end-cell of the macroconidia, which is rather characteristic in section Liseola and also by the presence of typical Liseola microconidia. The relationship of Lateritium and Liseola, on the other hand, is proved by the presence of a Gibberella with similar ascospores as a perfect stage in both groups. Section Saubinetti has a Gibberella as a perfect stage, but with more sickle-shaped ascospores.

AGRICULTURAL RESEARCH DEPARTMENT,
UNITED FRUIT COMPANY,
BOSTON, MASS.

NEW STUDIES ON STIPPLE-STREAK DISEASE OF POTATO

D. ATANASOFF

WITH TWO FIGURES IN THE TEXT

Various workers have shown during the last six or seven years that the so-called "virus" or mosaic disease of plants may overwinter in certain perennials in some instances and that some of the mosaic diseases can be brought over to plants on which they produce no pathologic changes, but in which their virus increases and from which plants it can be recovered with great ease and in very virulent form.

All this, however, does not appear to account for the sudden appearance and spread of some of these diseases under all conditions. Many and different may prove to be the explanations of such cases when the nature of these diseases becomes better understood.

The writer's studies on the stipple-streak disease of potato during the last few years, the results of which are discussed below, throw some new light on the mosaic problem. They appear to explain, partially at least, some of the many difficulties which the student of potato mosaic diseases has so often to deal with.

One of the common difficulties is the appearance of an entirely different disease in the artificially infected plants, even when all possible precautions have been taken to avoid external infection by insects or contamination of the virus. This apparently indicates that some and perhaps all of these diseases may be present in some potato plants or varieties in a "latent" form.

In Professor Quanjer's long experience with these diseases, as well as during the few years of the writer's work on them, stipple-streak was the disease which appeared most commonly on plants and in plots where it has been least expected.

The stipple-streak disease of potato, as already pointed out in the writer's first paper (1) on this subject, resembles superficially, in its primary form at least, some of the bacterial and fungus diseases of plants. It is, however, a "virus" disease *par excellence* and differs principally in no way from the infectious mosaic diseases of potato. Roughly speaking, it is a magnification of a mosaic disease. Every characteristic of the mosaic diseases—symptoms, infection period, effect on infected plants, and yield—is to be seen in it in a highly intensified form, which naturally leads to the appearance in some cases of new symptoms and conditions alien for the mosaic diseases. Working with this disease is therefore easier. This dis-

ease is unquestionably the most suitable object for fundamental studies on the degeneration diseases of potato.

It is generally known that not all potato varieties are equally susceptible to the different virus diseases of this plant. Some of them show more pronounced symptoms of such diseases and their yields deteriorate much more rapidly under their influence, while other varieties do this less. Still other varieties have never been seen to suffer from some of these diseases, though careful examination of such varieties has often shown that they are as subject to the disease or diseases in question as any other variety.

The various potato varieties are attacked in different degrees also by the stipple-streak disease, but whether this means that some varieties are more, others less, susceptible to this disease is not certain. It is certain, however, that plants of different varieties when attacked by this disease show in very different degrees and forms the effects of the infection; some of them are severely affected, they wilt and die in a short time, like the variety Schotsche Muis. Others, like the variety Non Plus Ultra, are much less so. While still others, though infected, are in no way injured or affected and continue giving an almost normal yield, even under extremely favorable conditions for the development of the disease. Such are the varieties Ashleaf and Koksiaan.

All these varieties are therefore susceptible to stipple-streak, but they possess a different "sensitiveness" for it. Whether there are potato varieties actually resistant to stipple-streak, in the true sense of the word, is not known and not very probable.

The existence of varieties such as the last two mentioned, which represent a kind of masked carrier of one of the most destructive and troublesome virus diseases of potato, is of great practical and scientific importance: First, because it makes possible the breeding of resistant varieties, but primarily because such varieties represent a great danger for the more "sensitive" potato varieties, that are susceptible to this disease. Such varieties are unquestionably a very important permanent source of inoculum in nature.

During the spring of 1921 there appeared a heavy stipple-streak epidemic in the districts of early potato culture in Holland, primarily in the variety known in Holland under the name Schotsche Muis and in England under that of Midlothian Early. This variety, which is the most productive and widely spread early variety in Holland, is the most sensitive of varieties susceptible to this disease, so far as the writer knows. Most infected plants were dead before the beginning of June. Few of them had formed any tubers.

The very rapid development of the disease and the very early death of the infected plants of this variety should naturally lead to a better knowl-

edge of this disease. But in spite of this the disease appears in a smaller or larger degree every year.

During the summer of 1921 the stipple-streak disease appeared in a lesser degree and in a lighter form also in various other varieties. The variety Non Plus Ultra, among other varieties, showed typical primary symptoms of stipple-streak, but the plants remained alive and green almost as long as the healthy plants of the same variety did and gave a normal yield. The varieties Ashleaf and Koksiaan,[1] which stood near plots of Schotsche Muis, where 75 per cent of the plants were infected, showed, upon a superficial examination, no symptoms of the disease. Both varieties were in excellent condition. A careful examination of their leaves, however, showed that some of them had one or more typical stipple-streak stipples or streaks, especially on their lower side. In these two varieties as well as in all varieties which are not very sensitive to the disease, the necrotic stipples and streaks appear first after the leaves have reached their full size so that as a rule they do not lead to the crinkling and distortion of the leaves, as is the case in the highly sensitive varieties.

Those plants of the above varieties which showed some streaks or stipples were considered as infected and their tubers were collected for further study.

During the following spring tubers of the above four varieties (Schotsche Muis, Non Plus Ultra, Ashleaf and Koksiaan) collected from stipple-streak plants were planted in special rows.

The Schotsche Muis tubers sent out few short and highly degenerated, curled, and crinkled plants, which died shortly after coming above the ground and formed none or very small tubers.

The Non Plus Ultra tubers gave rise to apparently normal and vigorous plants, on the leaves of which later appeared typical and numerous stipples and streaks. The plants remained alive almost as long and gave almost as good a yield as the healthy plants of the same variety did, though they were of a slightly smaller size than the healthy plants. All tubers showed brown necrotic areas and blisters, as is common of the Schotsche Muis stipple-streak tubers.

The tubers of Ashleaf and Koksiaan stipple-streak plants upon planting gave absolutely normal plants which remained in every respect as the healthy plants of the same variety and gave a good yield. Only about 10 per cent of the hills, which numbered eighty of each variety, had more or less black stipples and streaks on their otherwise normal leaves. The tubers of all plants of both varieties, however, upon digging showed distinct symptoms of the disease. The Ashleaf tubers showed brown necrotic areas and

[1] Known in England under the name Jersey Non Such.

blisters deep under the skin of the tubers, resembling somewhat Phytophthora infections, while those of the variety Koksiaan had a uniform dirty gray or brown skin.

The tubers of all of the above varieties harvested during the summer of 1922 were planted again in the spring of 1923 and gave similar results. The Schotsche Muis plants formed no tubers in the second generation of the disease, so that for the years 1923 and 1924 new tubers of primary stipple-streak plants were used. The progenies of the plants grown during the

FIG. 1. Stipple-streak infected potato plants of different varieties, of same age and grown under same conditions. Photographed June 15, 1924.

a. Two Schotsche Muis plants from originally healthy tubers, which tubers have been infected with stipple-streak, two and a half months before planting and four months before this photo was taken, by allowing infectious aphids to suck on their sprouts for 10 days. The plants are very dwarf and degenerated with curled and crinkled leaves, lower leaves dropping off and rusted, no new tubers are formed.

b. One Stein plant, progeny of a primary stipple streak plant, infected during the summer of 1923. Leaves curled and crinkled with numerous brown streaks and stipples. Lower leaves dropping off. Some new tubers are formed.

c. One Non Plus Ultra plant, fourth year stipple-streak infected, quite normal, but smaller than the healthy plants, leaves with deeper venation and with numerous stipples and streaks. Few quite large tubers are formed.

d and e. Ashleaf and Koksiaan plants, respectively; both fourth year stipple-streak infected. No symptoms of the disease are to be seen on the otherwise vigorous, normal, and healthy plants, except on the newly-formed large and numerous tubers.

summer of 1923 were planted for the third time during the spring of 1924 with practically the same results as at the beginning of the experiment in 1922. The variety Schotsche Muis already during the second year was so degenerated that no new tubers were formed. The variety Non Plus Ultra gave during the second, third and fourth generation somewhat smaller plants than the healthy ones, but during all of the three vegetative periods formed quite large tubers, though the yield in general was noticeably decreased. Ashleaf and Koksiaan showed no degeneration or running out in any way, except perhaps a slight decrease in yield.

During the winter of 1923–24 ten tubers of the infected material of each of the above four varieties were grafted on healthy tubers of the variety Schotsche Muis. In all cases the infection passed over into the grafted healthy tubers, which developed typical symptoms of the disease as is known for this variety. This shows that the material of the varieties Non Plus Ultra, Ashleaf, and Koksiaan used in the above field experiments actually did carry the virus of the stipple-streak disease.

FIG. 2. On the left and right are shown the yields of ten hills of Ashleaf and Koksiaan, respectively; both fourth year stipple-streak sick and belonging to the plants pictured in figure 1. In the middle is shown the yield of 60 (sixty) Schotsche Muis plants from originally healthy tubers, which tubers were artificially infected with stipple-streak by allowing infectious aphids to suck on their sprouts for 10 days, then incubated at 18° C. for two months and planted. These are the tubers of plants like those pictured in figure 1. All three varieties were harvested at the same time and when fully ripe.

During the summer of 1924 five young healthy Schotsche Muis plants were grafted with tops of each of the varieties Ashleaf and Koksiaan to see whether the plants were still infectious. The Ashleaf and Koksiaan plants from which was taken material for grafting, though originating from the slightly stipple-streak plants observed during the summer of 1921, showed absolutely no symptoms of the disease and were in every respect very normal, vigorous, and free from any disease, with exception of their tubers, which showed pronounced symptoms of the stipple-streak disease.

All of the grafted plants became infected and developed typical and very heavy symptoms of stipple-streak within 2–3 weeks, both on the leaves and tubers. All check plants remained healthy. All precautions were taken to protect the plants from coming in contact with insects.

This experiment proves definitely that the varieties Ashleaf and Koksiaan which, when infected with stipple-streak, may show slight primary symptoms of this disease only in very rare cases, while in the great majority of cases they show no symptoms whatever on their aerial portions, even in the third generation after the infection.

Under such conditions the probability that such varieties may eventually become wholly infected in all their lines and selections, provided they are visited by the stipple-streak transmitting aphids, is very great. It can therefore be taken for granted that at least a portion of the Ashleaf and Koksiaan plants under field conditions are infected with stipple-streak and carry in abundance the "virus," thus forming dangerous masked sources of infection for the more sensitive potato varieties.

In the old literature on the degeneration and running out of potato varieties has been described repeatedly a condition which resembles very much the condition described above. Simon, in 1782, for instance, writes that the first cases of degeneration in potatoes in Germany were noticed at the time (1770) when the so-called Viehkartoffel was introduced.[2] Before the introduction of this potato variety from England, he states, the disease had never been seen. The more common the growing of this variety became, the more common became also the disease among all other varieties, with the difference only that in some varieties the disease appeared more and spread more rapidly, in others less so. Localities where this variety was not grown remained free from the curl disease for a long time after, until at last, with the general introduction of this variety, the whole country became infected. The Viehkartoffel itself, writes Stockmar, as has been noticed also by Simon, Buchan-Hepburn, Ackermann, etc., (2) "does not

[2] This variety was introduced in Germany from England in 1770 at the time of the great food scarcity. It is a very prolific—but unsuited for human consumption—and unusually late variety, which has never hitherto been injured by the curl. It is stated that it had been brought by a sailor from America and has been known in England ever since 1711 under the name Yam or Surinam potato.

suffer from the curl disease and even though much poorer in quality, originally used only as animal food, it gradually replaced in most localities the common varieties, both red and yellow, which did suffer much from the disease."

The cause of the disease was considered by the early writer on this subject to lie in the cross pollination of the common potato varieties by the Viehkartoffel.

Stockmar (2), in 1801, made some experiments to establish the correctness of the above hypothesis. For this purpose he took tubers from the susceptible potato varieties from localities where the disease was not known. One portion of these tubers he planted away from, and the other portions next to, Viehkartoffeln. The first year all plants remained healthy. The second year he planted the tubers of the potatoes that had been next to Viehkartoffeln away from such potatoes and planted again other healthy potatoes near the Viehkartoffeln. Of the potatoes which the first year had been next to the Viehkartoffeln, he writes: "After the first leaves had hardly appeared above the ground I saw what I had suspected; more than half of these plants were curled, while the potatoes grown the previous year away from Viehkartoffeln, also those which this year are next to the latter did not show even the slightest symptoms of curling."

Unfounded as the old hypotheses regarding the nature of the curl disease may be, Stockmar's experiments prove nevertheless that the Viehkartoffel must have been a masked carrier of some mosaic disease, while the fact that in the second generation the plants showed distinct curling as soon as the first leaves appeared above ground justifies the supposition that the disease in question must have been stipple-streak, since it is the only one of the degeneration diseases by which the infected plants in the second generation show severe curling of the leaves as soon as they appear above the ground (1) provided that they are of a sensitive potato variety.

What has been said above of the varieties Ashleaf and Koksiaan may prove to be true also of other varieties, or of individual plants of other varieties, including even some of the most sensitive varieties to this disease. This supposition is somewhat strengthened by the recent work of Dorst (3) who has shown that a potato variety is in no case a genetically pure line, on account of the common occurrence of bud mutations.

Similar conditions as described above for stipple-streak must naturally exist in connection with other virus diseases of this plant, though so far this has not yet been experimentally established.

Oortwijn Botjes (5) and Murphy (4) have observed conditions which may be considered as similar with the condition treated in this paper, but they are of an entirely different nature. Oortwijn Botjes writes that in

one case, probably under the influence of the weather conditions, the progeny of a mosaic plant failed to show any symptoms of the disease, but apparently served as a source of infection for the neighboring plants. Murphy observed that under certain climatic conditions the symptoms of potato mosaic become less apparent or may completely disappear. The plants apparently recover from the disease and give a quite normal yield. When these plants or their progenies are grown again under conditions favorable for the development of the disease, they show its presence again.

SUMMARY

The potato varieties susceptible to stipple-streak possess a widely differing "sensitiveness" to this disease.

Some varieties, though infected by the disease, show no or only very slight symptoms of same, under all conditions. In other words, such varieties are masked carriers of the virus of this disease under field conditions.

INSTITUT VOOR PHYTOPATHOLOGIE,
WAGENINGEN, HOLLAND.

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SCAB OF CHRISTMAS BERRY, PHOTINIA ARBUTIFOLIA LINDL., DUE TO FUSICLADIUM PHOTINICOLA N. SP.

R. L. McCLAIN

WITH TWO FIGURES IN THE TEXT

About the year 1912 Professor W. T. Horne of this Division became interested in a scab disease occurring on the California Christmas berry, *Photinia arbutifolia* (*Heteromeles arbutifolia* Roerm.) This disease was found on leaves and berries and closely resembles scab on pears and apples. At his suggestion the writer has made a study of the fungus causing Christmas berry scab, particularly in comparison with the pear scab fungus (*Venturia pirina* Aderh.), which it seemed most closely to resemble.

The Christmas berry is a plant peculiar to California and the islands off the coast. It is an evergreen shrub with many branches given off from a short, thick trunk. The leaves are tough, leathery, shiny and of deep green color. The berries, which are bright red, are borne in large clusters from October to February. The branches and berries make a striking appearance and are much used for decorations.

DESCRIPTION OF THE DISEASE

As already stated, the symptoms of the scab on the Christmas berry are very similar to those on the apple and pear. The fungi are confined to the surface layers of cells of the hosts but the tissue beneath may be killed. If the Christmas berry leaves are attacked when quite young, they may be killed, while infection occurring after the leaves have hardened (Fig. 1) produces more or less rounded, olive-green spots on either side. Old infections become gray in the center, surrounded by an olive-green, slightly zonate margin of new conidia. These old leaves may change from green to various shades of red and brown. On the green berries the scabby patches almost completely cover the surface, causing them to shrivel. In the winter of 1923–24 the scab was not at all common around Berkeley, California, and in the fall of 1924 no infection was found. From these observations we are led to believe that the fungus does very little damage. In the wild state the Christmas berry is host to so many insect pests that it is difficult to determine the injury from any one organism.

METHODS

The Christmas berry scab fungus was isolated in single-spore cultures by both hanging-drop and plate methods. The spores were taken from typi-

cal scab spots on the leaves of the Christmas berry collected from a shrub in the Northbrae district of Berkeley, California, in September, 1923. The pear scab fungus was isolated by the same methods from a pear fruit in October, 1923.

In order to make comparative studies of the fungi, the following culture media were used: standard nutrient agar, prune juice, prune agar, bread and prune juice, bread and Christmas berry leaf juice, cornmeal and pear juice, and steamed rice.

Fifteen cultures of each fungus in each of the above series, twelve for inoculation and three for checks, were used throughout this study. Single-spore cultures secured by the plate method were used in making transfers. All cultures were kept in the laboratory at room light and temperature.

Inoculations were made in the laboratory and in the greenhouse both on Christmas berry and pear trees, and in the field on Christmas berry. The spores or mycelium were either laid on the wet leaves or the spores sprayed on with an atomizer. Both pure cultures of the fungi and spores produced on the respective hosts were used.

COMPARATIVE MORPHOLOGY

Only the imperfect or Fusicladium forms of the fungi were found and studied. The chief differences are found in the shape and character of the conidiophores and conidia (Fig. 2). The conidiophores of both fungi are about $8 \times 30\,\mu$ in size, usually one-celled and olive-green in color. Those occurring on the Christmas berry are smooth, usually slightly enlarged at the end and at the base, while those of the pear scab fungus are distinctly knobby, suggesting that several spores had been given off from a sporophore. The conidia of both fungi vary greatly in size and shape, particularly those of the pear scab fungus. The conidia of the Christmas berry scab fungus are about $10 \times 22\,\mu$ average size, distinctly pyriform, broadly truncate at base, outer end well rounded, the greatest diameter below the middle. In contrast, those of the pear scab fungus are about $8 \times 22\,\mu$ average size, very slightly pyriform, narrowly truncate or not at all, frequently well pointed at both ends, widest part typically near the middle.

It will be noted by the chart that the pear scab fungus in cultures is uniformly darker in color than the Christmas berry scab fungus. The most striking difference is found on steamed rice in which the former is almost black while the latter is the characteristic olive-green. These differences were so pronounced that the fungi could easily be distinguished from each other.

In general, conidia were produced in abundance by the pear scab fungus while none or very few were produced by the Christmas berry scab fungus.

TABLE 1.—*Comparative cultural characteristics of Fusicladium pirina and F. photinicola*

Medium	Fungus	Color*	Cultural Characteristics
Nut. agar	Chr. b. scab	Deep grayish olive	Tough button of mycelium in center of colony, mycelium regular—*i. e.*, not breaking up into chlamydospores, very few conidia.
	Pear scab	Dark olive	Almost all of mycelium breaking up into chlamydospores, conidia abundant.
Bread and prune juice	Chr. b. scab	Deep olive	Tough mycelium, regular, no conidia.
	Pear scab	Dark olive	Chlamydospores abundant, conidia numerous.
Steamed rice	Chr. b. scab	Deep grayish olive	Mycelium regular, no conidia.
	Pear scab	Deep olive	Mycelium regular, conidia fairly numerous.
Corn meal and pear juice	Chr. b. scab	Deep olive	Mycelium very compact, tough, an occasional conidium.
	Pear scab	Dark olive	Mycelium very smooth, tough, an occasional conidium.
Bread and Chr. b. leaf juice	Chr. b. scab	Olive green	Mycelium regular, very few conidia.
	Pear scab	Olive green	Mycelium having numerous enlargements, conidia abundant.

* Ridgway's Color Standards.

From these and the following we are led to believe that the fungus causing scab on the Christmas berry is distinct from that causing scab on the pear.

INOCULATIONS

While no infection was secured in the field or in the greenhouse by either fungus, infection of the Christmas berry scab fungus on the leaves of Christmas berry plants growing under bell jars in the laboratory was secured by using spores produced in a natural scab infection. No infection was secured on pear leaves under the same conditions.

IDENTIFICATION

Other Fusicladia known to occur in California are: apple scab, *Venturia pomi* Aderh.; loquat scab, *Fusicladium eryobotryae* Sciala.; and an unidentified species attacking *Cotoneaster crenulata*. While no cultural studies of these fungi have been made, it appears from their descriptions that they

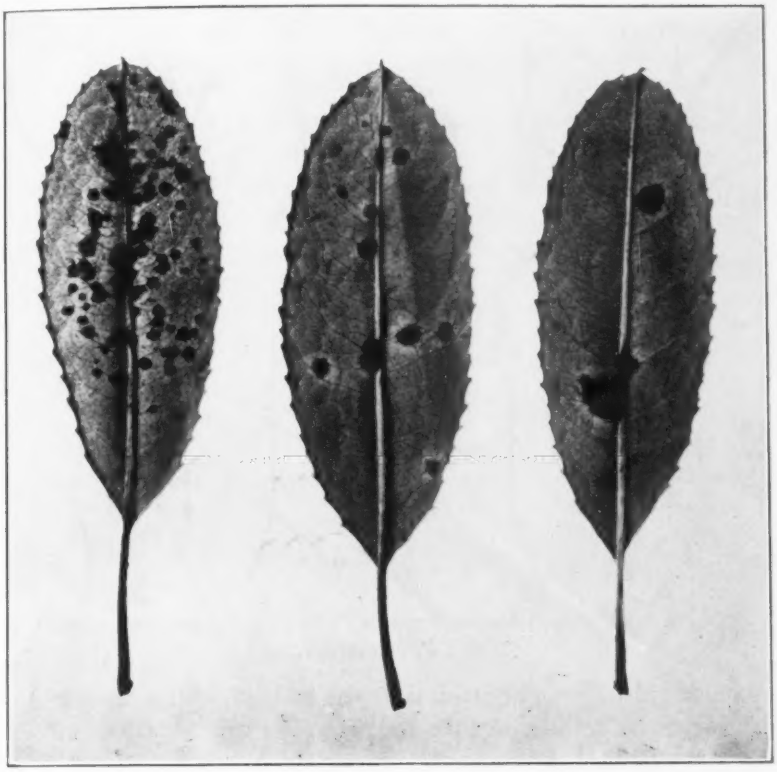

Fig. 1. Scab infection on lower side of Christmas berry leaves.

are distinct from the fungus causing Christmas berry scab. For these and the foregoing reasons it seems advisable to describe the latter as a new species.

Fusicladium photinicola n. sp.

Conidiophores $8 \times 30\,\mu$ in size, usually one-celled, olive-green in color, smooth, slightly enlarged at both ends. Conidia average about $10 \times 22\,\mu$ in size, distinctly pyriform, broadly truncate at base, other end well rounded, largest diameter below the middle, olive-green in color. Mycelium of same color, $5–7\,\mu$ in diameter; in cultures, the colonies under the low power of the microscope showing radiating, irregular, wavy threads of

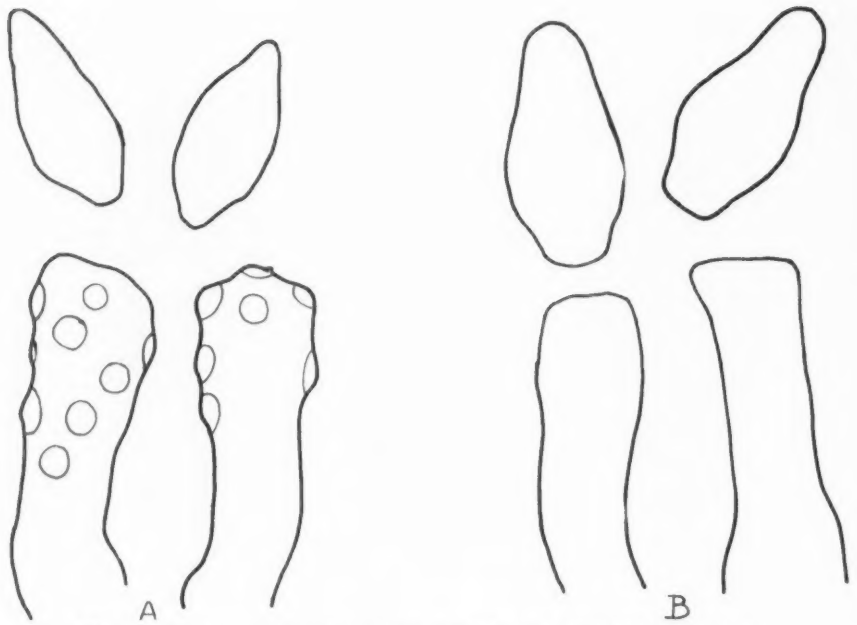

FIG. 2. Conidia and conidiophores, × 500. (A) *Fusicladium pirina*, (B) *F. photinicola*.

mycelium and producing appresoria at the ends of certain filaments. The conidia germinate readily, but the fungus grows very slowly in cultures.

DIVISION OF PLANT PATHOLOGY,
DEPARTMENT OF AGRICULTURE,
UNIVERSITY OF CALIFORNIA,
BERKELEY, CALIFORNIA.

THE EFFECT OF CALCIUM CARBONATE ON BORDEAUX MIXTURE

E. R. DEONG AND W. C. ROOT

The use of hydrated lime in the preparation of Bordeaux has brought up the question of calcium carbonate as an impurity of the lime, and its action on the physical properties of the mixture. Data on this question

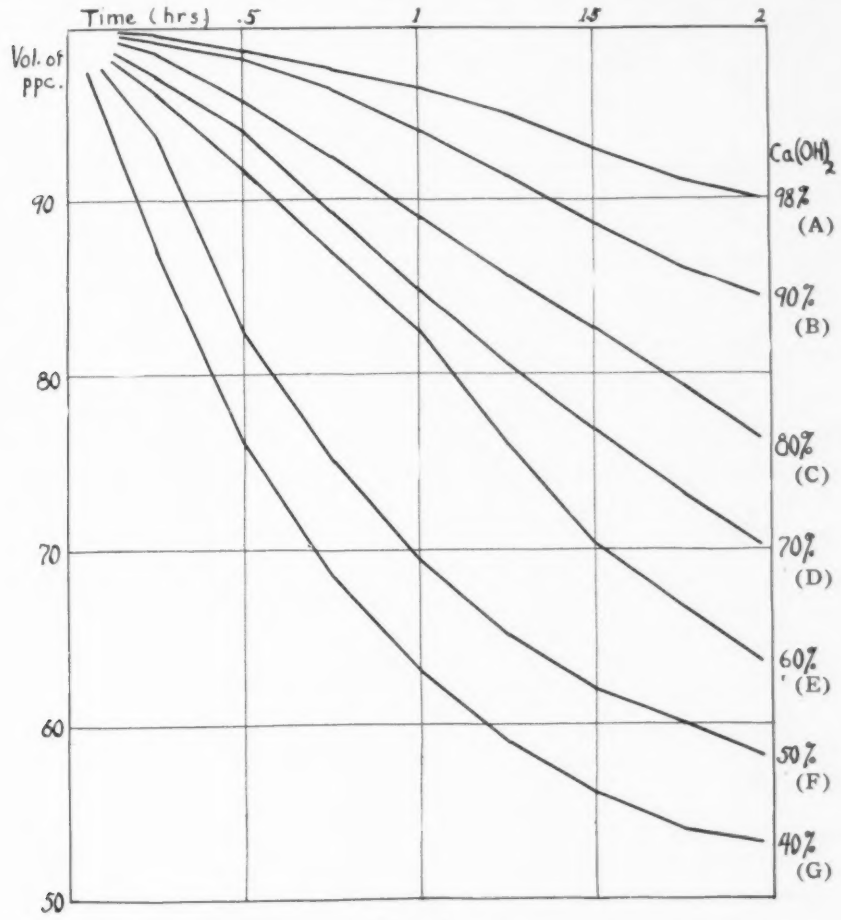

Fig. 1

Average rate of settling of 8-8-100 mixtures.

were not available, so a report of the experiments made to determine this point is offered as a possible aid to others.

Two sets of experiments were performed, (a) with pure calcium hydroxide to which known quantities of calcium carbonate were added; (b) samples of hydrated lime which upon analysis showed the amount of carbonate desired for experimental purposes. The calcium hydroxide in (a) was prepared by firing hydrated lime until all moisture and carbon dioxide were driven off.

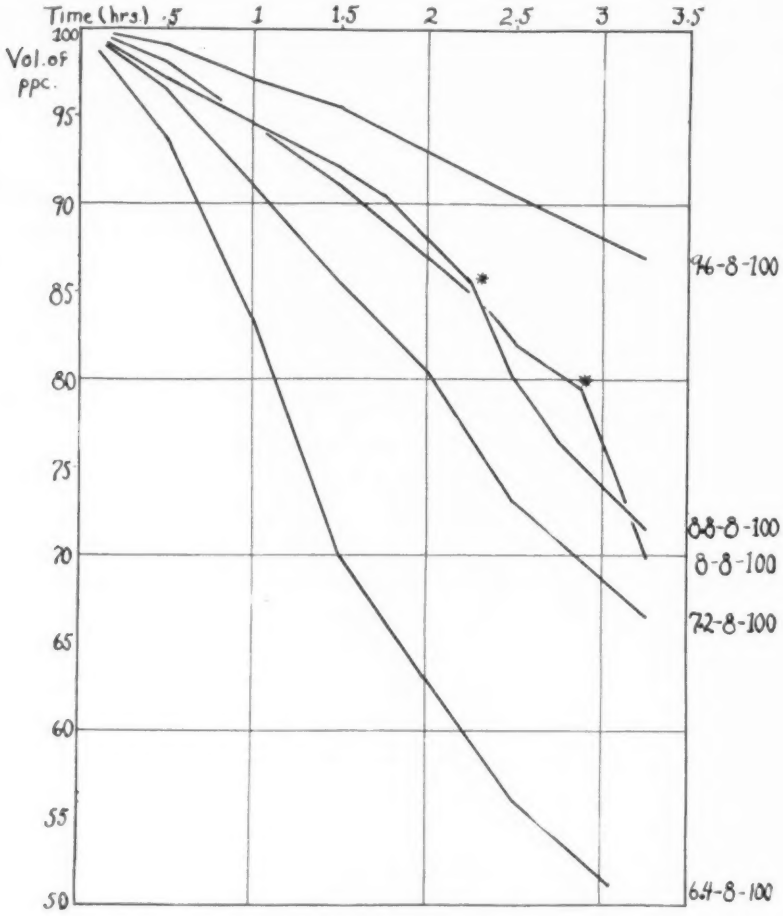

Fig. 2

Comparative rates of settling of mixtures containing various ratios of $CaO - CuSO_4$

* - $Fe(CN)_6^{=}$ added.

The Bordeaux solutions were made as follows: 1.32 gm. finely powdered $Ca(OH)_2$, or a mixture of $Ca(OH)_2$ and $CaCO_3$ of known composition was mixed in a beaker with 50 cc. of water. Fifty cc. of a solution of copper sulfate (31.2 gm. $CuSO_4 \cdot 5H_2O$ to 1 liter) were then prepared and the two solutions combined, thoroughly stirred and then poured into a 100-cc. graduate. The volume of precipitate was then noted at definite intervals of time. The rate of settling, as shown in figure 1, was taken as an indication of the physical qualities of the mixture. The film formation, as seen under the microscope, corresponded to the settling test, but the distinction was less sharp; A and B showed a continuous durable film. The film in C broke early and from then on it lacked from thirty to fifty per cent of being continuous. The difference in color was also quite marked, A to C inclusive being a deep blue; D, pale blue; E, a bluish green; and F, a greenish blue.

The curves in figure 1 show a striking effect of a high carbonate content on the physical properties of the Bordeaux mixture. None of these mixtures showed free copper with the potassium ferro-cyanide test, but the character of the precipitate after standing for two or three hours, color and film structure all showed deterioration. Such proportions of calcium carbonate are possible in hydrated lime that stands for any length of time, as shown by the following data. The samples were small, containing not more than two or three pounds each, but they are an indication of what occurs on the outside of a sack.

TABLE 1.—*Percentage of calcium hydroxide found in samples of hydrated lime*

Container	Original per cent of $Ca(OH)_2$	Date of Analysis	Final per cent of $Ca(OH)_2$
Air-tight tin can	96.9 (January 1st)	February 3d	96.8
Paper bag			
Outer part	96.9 (January 1st)	February 5th	74.4
Inner part	96.9 (January 1st)	February 5th	90.4
Cloth sack			
Outer part	96.9 (January 1st)	February 18th	51.2
Inner part	96.9 (January 1st)	February 16th	96.8

Coarse hydrated lime also hastened the settling rate but was not as detrimental on the whole as a high carbonate content.

Increasing the proportion of copper sulfate retards the settling rate, as shown in figure 2, and may, if necessary, be used to overcome this difficulty.

CONCLUSIONS

The data show that the rate of settling increases almost proportionately to the amount of carbonate and that this should not be greater than twenty per cent and preferably less. Lime containing from thirty to sixty per cent of carbonate makes a very poor type of Bordeaux. The settling rate is also increased by using poorly pulverized lime; the larger the particles, the faster the precipitate settles. The rate of settling is retarded by increasing the proportionate amount of copper sulfate. Artificially prepared and natural occurring carbonated limes produced practically the same physical qualities in the Bordeaux solution.

PHYTOPATHOLOGICAL NOTES

Verticillium wilt of tomato.—While studying the Grand Rapids disease of tomatoes in the field in northern Ohio and in Erie County, Pa., in Sept., 1924, it was found that this disease was occurring in considerable amounts up to 25 per cent in tomato fields, some of which were supposed to have the Fusarium wilt only. One such field of one-half acre showed 90 per cent infection with the combined organisms.

On examination of stems with a hand lens and later in sections under the microscope, both the bacterial and fungus parasites were found to occur in the same field, sometimes in the same plant. As the season was late and the plants far gone, the diseases could not readily be distinguished by casual examination. By cutting the stem across within 6 or 8 inches of the top, however, the differences were clearly evident. In the case of the bacterial disease, the vascular region showed a yellowish discoloration extending into pith and cortex, but no browning. In stems with the fungus disease, on the other hand, a dark brown stain was evident, confined to the narrow vascular ring. In some cases cuts had to be made much lower on the stem before this brown color was evident, but more often it extended to the very tip of the stem.

Specimens of these discolored stems brought to the laboratory for further study and for culturing the fungus have given evidence that the greater part of the fungus wilt was caused by a Verticillium resembling *V. albo-atrum*. Successful infections have been obtained on tomatoes in the hot-house with the Verticillium isolated which was again cultured from the inoculated plants.

That the two fungus diseases of tomato should be confused in the field is not strange since Carpenter[1] states that "The wilt diseases of the several plants brought about by *F. vasinfectum* and *V. albo-atrum* manifest the same symptoms, so that the real cause of the trouble is safely to be determined only by cultural means." Although in England *Verticillium albo-atrum* is a more serious wilt disease of tomatoes than is Fusarium, and although it is also the cause of destructive wilt in numerous plants in America, notably eggplant, potato and okra, no mention has been found in literature of a Verticillium wilt of tomato in the United States. Suc-

[1] Carpenter, C. W. Wilt diseases of okra and the Verticillium wilt problem. Jour. Agr. Res., 12: 538. 1918.

cessful cross-inoculations on tomato with the eggplant strain of *Verticillium albo-atrum* have been made however by Jagger.[2]

The demonstration of Verticillium wilt where Fusarium was supposed to be causing the trouble suggests that perhaps this fungus is doing damage in other places in northern tomato fields where cool temperatures would favor its ravages and retard Fusarium.—MARY K. BRYAN.

[2] Jagger, I. C., and Stewart, V. B. Some Verticillium diseases. Phytopath. 8: 15–19. 1918.